BBC

PROF STEPHEN HAWKING REMEMBERED

THE UK'S BIGGEST SELLING ASTRONOMY MAGAZINE

Sky at Night

MAY 2018

JUPITER rediscovered

New results from the Juno mission solve the gas giant's most enduring mysteries

An InSight into MARS

The lander set to look deep into the Red Planet's interior

TRAVELS with a telescope

- How to plan
- What to pack
- Where to go

INCLUDING Europe's darkest skies

CLASSIC EPISODE
How an 18th century astronomer mapped the night sky

VIDEO INTERVIEW
NASA's new mission to explore the Martian interior

ASTRO QUIZZICAL
Astrophysicist Dr Jillian Scudder answers your cosmic questions

CELESTRON®
TECHNOLOGICALLYSUPERIOR
THE NEXSTAR EVOLUTION KEEPS EVOLVING
NexStar®
EVOLUTION
8" EdgeHD with StarSense
Now paired together, enjoy the EdgeHD 8" optics and StarSense AutoAlign on the Evolution Mount. All controlled from your favourite iOS or Android phone or tablet with the new SkyPortal App.
Upgrade your NexStar Evolution for longer exposure astrophotography with the new Evolution equatorial wedge.
NexStar Evolution 8" EdgeHD with StarSense AutoAlign
iPAD and iPHONE SHOWN NOT INCLUDED.
NEXSTAR EVOLUTION HD
CELESTRON
NexStar Evolution 6" SCT
NexStar Evolution 9" SCT
Equatorial Wedge
Available from specialist astronomy retailers and selected other dealers nationwide.
Celestron is distributed in the UK & Ireland by David Hinds Limited. Trade enquiries welcomed.
www.celestron.uk.com
Sky at Night MAGAZINE
REVIEWED IN ISSUE 112 SEPTEMBER 2014

Welcome

Juno what's in this issue? Lots of Jupiter!

With mighty planet Jupiter at opposition this month, and highest and brightest to see for the year, what better time to bring you up to date with the Juno mission currently in orbit around it? The probe has truly rewritten much of what we thought we knew about this gas giant, providing new views of its poles, peering through its visible cloud layer deep into the interior and measuring its ferocious magnetic environment. Ben Evans takes a look at the Juno mission on page 36, while on page 49 there's more in the Sky Guide from Pete Lawrence on how best to see the planet and its four main moons.

For an even better view of Jupiter, the islands of the Canaries beckon. On page 72, Spanish-based travel writer Inka Piegsa investigates the best places to visit on the Canaries to take advantage of their unique dark skies, which have turned the three most westerly islands of this mid-Atlantic archipelago into a stargazing Mecca.

To record the unique night skies of places like La Palma or La Gomera, it's easier than ever to take an astrophotography setup abroad with you thanks to smaller, lighter equipment. On page 66, Will Gater considers how best to plan an astronomy holiday so that you and your equipment get where you're going with the least hassle and the most reward. And, on page 94, Gary Palmer tests out the view through the latest short-tube refractor, which is an ideal size for packing safely in carry-on luggage to arrive intact and ready to use on your next holiday.

Enjoy the issue!

Chris Bramley Editor

PS Our next issue goes on sale 17 May.

This month's contributors include...

Sanjeev Gupta
Planetary geologist

The official sedimentary geologist for the Curiosity rover mission reveals what's exciting him about the Martian rocks. *Page 21*

Chris Murphy
Astrophotographer

Practical tips on how to combine separately shot skies and landscapes from the award-winning New Zealander. *Page 84*

Inka Piegsa
Travel writer

The Canary Islands aren't just about year-round Sun. Inka will convince you that they're about gloriously dark skies too. *Page 72*

Laura Nuttall
Astrophysicist

Laura takes time off from her studies into gravity to browse through Marcus Chown's fun new book about the Big Bang. *Page 102*

How to contact us

Subscriptions, binders and back issues
03330 162119
8am to 8pm, Mon to Fri; 9am to 1pm, Sat for orders
Calls from landlines will cost up to 9p per minute. Call charges from mobile phones will cost between 3p and 55p per minute but are included in free call packages.

Editorial enquiries
0117 314 7411
9.30am to 5.30pm, Mon to Fri

Advertising enquiries
0117 300 8276

Print subscription enquiries
bbcskyatnight@buysubscriptions.com

Digital subscription enquiries
bbcskyatnightdigital@buysubscriptions.com

Editorial enquiries
contactus@skyatnightmagazine.com

Subscription enquiries
UK enquiries: FREEPOST IMMEDIATE MEDIA
(please write in capitals)
Overseas enquiries: PO Box 3320, 3 Queensbridge, Northampton, NN4 7BF, UK

Editorial enquiries
BBC *Sky at Night* Magazine, Immediate Media Co Bristol Ltd, Tower House, Fairfax Street, Bristol, BS1 3BN

Sky at Night Lots of ways to enjoy the night sky...

TELEVISION
Find out what *The Sky at Night* team will be exploring in this month's episode on page 19

ONLINE
Visit our website for reviews, competitions, astrophotos, observing guides and our forum

FACEBOOK
All the details of our latest issue, plus news from the magazine and updates to our website

PODCAST
Listen to the *BBC Sky at Night Magazine* team and guests discuss the latest astro news

iPHONE/iPAD
Get each month's issue on your iPad or iPhone, now with bonus image galleries

TWITTER
Follow @skyatnightmag to keep up with the latest space stories and tell us what you think

CONTENTS

C = on the cover

Features

NEW TO ASTRONOMY?
Get started with The Guide on page 78 or by visiting our online glossary at: www.skyatnightmagazine.com/dictionary

Regulars

MAY'S BONUS CONTENT

HOW TO FIND IT

Visit **www.skyatnightmagazine.com/bonuscontent**, select May's bonus content from the list and enter the authorisation code **3ESTA9N** when prompted

THERE'S MORE ONLINE

May highlights

The Sky at Night: classic episode

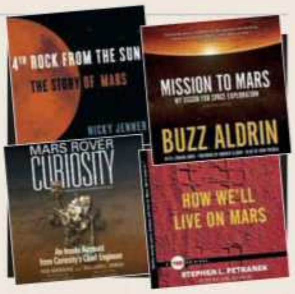
This classic episode from 1979 sees Patrick Moore discuss the life and legacy of Charles Messier, the 18th century French comet hunter whose famous 'Messier catalogue' is still being used by astronomers today. Patrick reveals the history of Messier's catalogue and looks at some of the well-known celestial objects included in it.

Examining the Martian interior

NASA's Bruce Banerdt on how the InSight mission will explore the inner workings of the Red Planet.

Astroquizzical: your questions answered

Astrophysicist Dr Jillian Scudder fields some of the cosmic queries posed by readers on social media.



Audiobook extracts: a celebration of Mars

Download audio excerpts from a range of books on humanity's relationship with this iconic planet.

And much more...

- ▷ Hotshots gallery
- ▷ Eye on the sky
- ▷ Extra EQMOD files
- ▷ Binocular tour
- ▷ Equipment review guide
- ▷ Desktop wallpaper
- ▷ Observing forms
- ▷ Deep-sky tour chart

EVERY MONTH Virtual Planetarium

With Paul Abel and Pete Lawrence

Explore May's night-sky highlights with Paul and Pete

BBC Sky at Night MAGAZINE IMMEDIATE MEDIA Co

***BBC Sky at Night Magazine* is published by Immediate Media Company Bristol Limited under licence from BBC Worldwide, who help fund new BBC programmes.**

EDITORIAL
Editor Chris Bramley
Art Editor Steve Marsh
Production Editor Dave Golder
News Editor Elizabeth Pearson
Staff Writer Iain Todd
Reviews Editor Paul Money

CONTRIBUTORS
Paul Abel, Shaoni Bhattacharya, Jon Culshaw, Lewis Dartnell, Glenn Dawes, Ben Evans, Mark Garlick, Will Gater, Sanjeev Gupta, Tim Jardine, Brian Jones, Pete Lawrence, Chris Lintott, Chris Murphy, Laura Nuttall, Gary Palmer, Steve Richards, Steve Sayers, Giles Sparrow, Paul Sutherland, Stephen Tonkin, Paul Wootton

ADVERTISING SALES
Advertising Managers
Neil Lloyd (0117 300 8276)
Tony Robinson (0117 314 8811)
Inserts Laurence Robertson (00 353 87 690 2208)

PRODUCTION
Production Director Sarah Powell
Production Coordinator Derrick Andrews
Ad Services Manager Paul Thornton
Ad Co-ordinator Emily Thorne
Ad Designers Cee Pike, Andrew Hobson
Reprographics Tony Hunt, Chris Sutch

LICENSING
Director of Licensing and Syndication Tim Hudson
International Partners' Manager Anna Brown

MARKETING
Head of Circulation Rob Brock
Head of Marketing Jacky Perales Morris
Marketing Executive Craig Ramsay
Head of Press and PR Ridhi Radia

PUBLISHING
Publisher Jemima Dixon
Managing Director Andy Marshall

MANAGEMENT
CEO Tom Bureau

BBC WORLDWIDE, UK PUBLISHING
Director of Editorial Governance Nicholas Brett
Director of Consumer Products and Publishing Andrew Moultrie
Head of UK Publishing Chris Kerwin
Publisher Mandy Thwaites
UK Publishing Coordinator Eva Abramik

UK.Publishing@bbc.com
www.bbcworldwide.com/uk anz/ukpublishing.aspx

SUBSCRIPTION RATES
Annual subscription rates (inc. P&P): UK cheque/credit card £62.40; Europe & Eire Airmail £75; rest of world airmail £85. To order, call 0844 844 0260

We abide by IPSO's rules and regulations. To give feedback about our magazines, please visit immediate.co.uk, email **editorialcomplaints@immediate.co.uk** or write to The Editor, *BBC Sky at Night Magazine*, Immediate Media Co., Tower House, Fairfax Street, Bristol, BS1 3BN.

Audit Bureau of Circulations
20,693 (combined; Jan-Dec 2017)

ISSN 1745-9869

COVER MAIN IMAGE: NASA/JPL-CALTECH/SWRI/MSSS/GERALD EICHSTADT/SEAN DORAN. THIS PAGE: KRZYSZTOF JAKUBCZYK/ALAMY STOCK PHOTO, AUTHOR ATTILA MUZLINGER/ROMANIA/EXPEDITION SARM AND ASTRO TRAVELS/LA PALMA 2016, WWW.SECRETSTUDIO.NET, NASA/JPL-CALTECH/SWRI/MSSS, BBC

Creation of the crustacean

Thanks to the meticulous note-taking of ancient stargazers, astronomers today are able to pinpoint when this familiar object first appeared

CHANDRA X-RAY OBSERVATORY, HUBBLE SPACE TELESCOPE, SPITZER SPACE TELESCOPE, 14 MARCH 2018

In the year 1054 astronomers from various countries reported the appearance of a 'new star' in the night sky; something that must have been quite a shock to those keeping a regular eye on the heavens. This celestial newcomer is now thought to have been the exploding star – or supernova – that created the Crab Nebula.

This new image of the nebula was taken in X-ray, optical and infrared to reveal a luminous, wispy object with a defined structure.

The Crab Nebula is a 'supernova remnant'; a region of gas left over from that ancient stellar explosion. It is illuminated by a type of star known as a pulsar, formed when an aging star collapses as it runs out of fuel to create a bright, rapidly spinning object.

There's a lesson to be learned from the Crab Nebula: keep a note of what you see in the night sky, as your observations could be a big help to astronomers scouring the skies centuries from now.

X-RAY: NASA/CXC/SAO; OPTICAL: NASA/STSCI; INFRARED: NASA-JPL-CALTECH

▲ Orion's stellar nursery

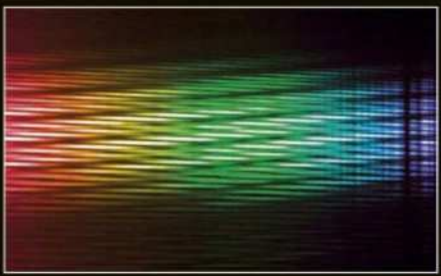
ATACAMA LARGE MILLIMETER/ SUBMILLIMETER ARRAY, VERY LARGE TELESCOPE, 7 MARCH 2018

This composite image of part of the Orion Nebula shows red, wispy filaments of cold gas, invisible to the human eye but not to the power of modern telescopes. Stars are born in regions like this when pockets of gas collapse under gravity, compress and form protostars. This is true of the Trapezium Cluster, the collection of blue-white stars in the upper left, which formed out of the surrounding nebula.

▼ Artistic observations

MATISSE INSTRUMENT, VERY LARGE TELESCOPE INTERFEROMETER, 5 MARCH 2018

The name of the new instrument at ESO's Paranal Observatory is appropriate, considering the beautiful colours produced during its first observations. MATISSE analyses light from the regions around young stars, where planets are forming. This data was collected during infrared observations of the star Sirius, so does not reflect what would be seen with the human eye.



▲ Feeding funnel

HUBBLE SPACE TELESCOPE, 12 MARCH 2018

It's easy to see why NGC 1015 is called a 'barred spiral galaxy', given the huge bar of stars and gas cutting through its centre. Bar structures are thought to exist in around two thirds of spiral galaxies, including the Milky Way. Astronomers believe these bars funnel gas and energy from the galaxy's arms to its core, feeding the supermassive black hole at its centre.

◀ A rose in the clouds

JUNO SPACECRAFT, 7 FEBRUARY 2018

A raging storm in Jupiter's northern hemisphere looks rather like a rose in this image taken by the NASA Juno spacecraft. It shows just how close the Juno mission is getting to the gas giant, helping scientists on Earth learn the secrets hidden beneath the surface. This image was taken a mere 12,000km above the cloud tops.

A relic of the Universe ▶

HUBBLE SPACE TELESCOPE, 19 MARCH 2018

The centre galaxy in this image is NGC 1277, a lenticular galaxy located about 220 million lightyears from Earth that is about 12 billion years old. Given that the Big Bang is thought have occurred 13.8 billion years ago, this makes NGC 1277 a true relic of the cosmos.

YOUR BONUS CONTENT A gallery of these and more stunning space images

Bulletin

The latest astronomy and space news written by **Elizabeth Pearson**

PLUS CUTTING EDGE

Our experts examine the hottest new astronomy research papers

RUBY/ALAMY STOCK PHOTO

Stephen Hawking dies aged 76

The visionary cosmologist spent his life bringing science to the masses

"We are deeply saddened that our beloved father passed away today," announced Stephen Hawking's children Lucy, Robert and Tim in a statement on 14 March. "He was a great scientist and an extraordinary man whose work and legacy will live on for many years. His courage and persistence with his brilliance and humour inspired people across the world. He once said: 'It would not be much of a Universe if it wasn't home to the people you love.' We will miss him forever."

Hawking's funeral took place in Cambridge on 31 March and his ashes will be interred in Westminster Abbey – alongside such other great British scientists as Charles Darwin and Isaac Newton – in a ceremony later this year.

Hawking gained his PhD from Cambridge in 1966, despite the onset of motor neurone disease. He went on to apply his theories about space-time singularities and black holes to the entire Universe, leading to the first mathematical examination of the Big Bang theory.

Though Hawking continued to make great cosmological breakthroughs, he is perhaps best known for his mission to make those discoveries accessible to the public. In 1988, Hawking published his first book about his work, *A Brief History of Time*, which spent a record-breaking 237 weeks on the *Sunday Times* bestseller list.

Following the book's success, Hawking continued to communicate complex theories about our Universe to a global audience. He also regularly gave lectures and interviews, wrote more books and appeared on such diverse television shows such as *Star Trek: The Next Generation* and *The Simpsons*.

In his later years, Hawking used his celebrity to promote awareness of scientific issues including the dangers of artificial intelligence, the search for extraterrestrial intelligence and the need for humanity to become a multi-planetary species.

▸ **See Comment, right**
▸ **Read our tribute on page 32**

COMMENT
by Chris Lintott

My first encounter with Professor Stephen Hawking's work goes back to my time at school, long before I interviewed him on *The Sky at Night*, when I requested a copy of *A Brief History of Time* from my parents.

The bookshop had sold out, so they grabbed a copy of another book by Hawking – a technical series of lectures – which I stared at for hours, hoping to make some sense out of it through sheer force of will. The second sentence – I still remember it now – was, 'It is obvious that space is time-like.' It may have been obvious to Hawking and his audience, but it wasn't obvious to me!

I eventually did get hold of *Brief History* and, like others, struggled with the cacophony of concepts that thread through its pages. But I've come to admire it: it contains the distinctive voice of a populariser determined to bring his audience to the very cutting edge. It's a voice we will all miss.

CHRIS LINTOTT co-presents *The Sky at Night*

NEWS IN BRIEF

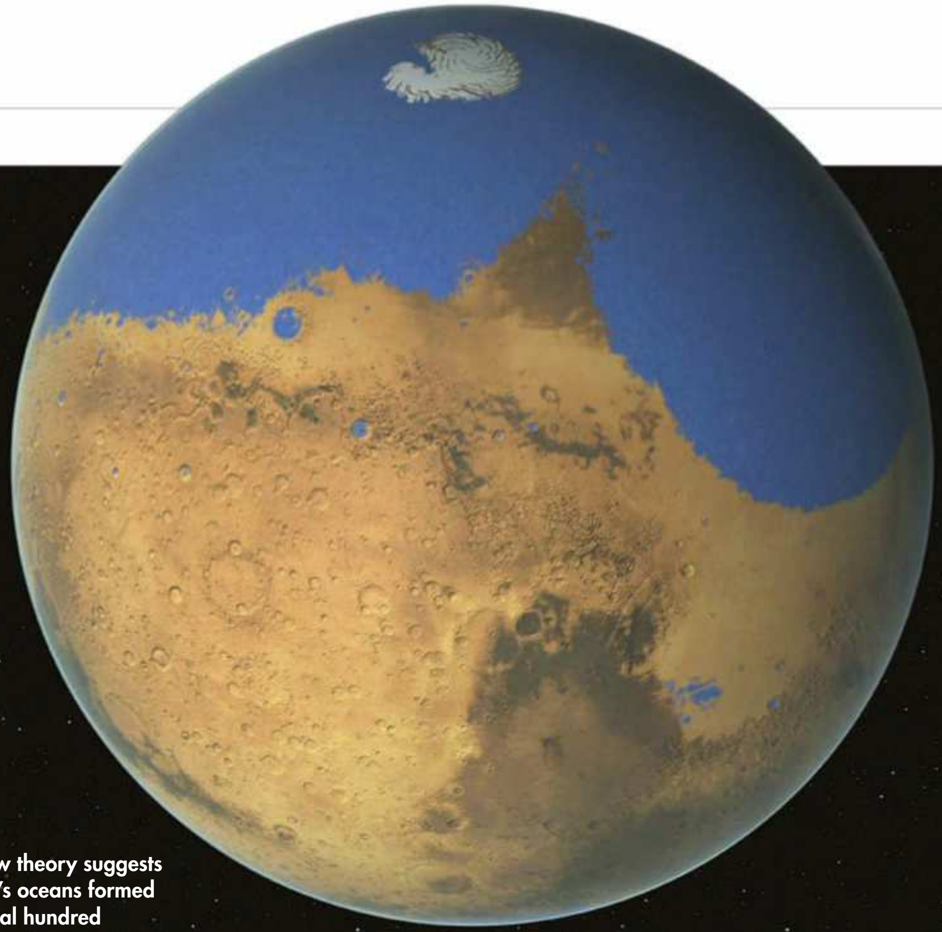
67P SHAPED BY A COLLISION

The latest simulations have shown that 67P/Churyumov-Gerasimenko, the double-lobed comet visited by the Rosetta mission from 2014-16, could be the result of a high-speed crash. The simulations show that when comets collide, only a small amount of material is vaporised. The rest remains in large enough pieces to clump back together and form a new comet within a few days. High-speed collisions are more common in the current Solar System, so 67P could have conjoined relatively recently.

UK TO LEAD ARIEL MISSION

ESA has given the green light to a new exoplanet-characterising space observatory, ARIEL (Atmospheric Remote-sensing Infrared Exoplanet Large-survey). The mission will study over 1,000 known exoplanets, teasing out details about the composition of their atmospheres. The planning and leadership of ARIEL will be based in the UK, but the spacecraft is going to be built by over 60 institutions in 15 different European nations. The launch is scheduled for 2028.

ESA/ROSETTA/MPS FOR OSIRIS TEAM MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA, CARDIFF UNIVERSITY, NASA/GSFC, GEMINI OBSERVATORY/NSF/AURA/KECK/JEN MILLER, NORTHROP GRUMMAN, ESO/M. KORNMESSER



A new theory suggests Mars's oceans formed several hundred million years earlier than once thought

Mars's oceans APPEARED EARLY

New theory could explain why Mars's water has disappeared

Mars's oceans could have been around several hundred million years earlier than formerly believed. A novel scenario suggests that the oceans formed four billion years ago at the same time as the largest volcanic structure on Mars, Tharsis – the volcanic plateau near the planet's equator that is home to Olympus Mons.

"The assumption was that Tharsis formed quickly and early, rather than gradually, and that the oceans came later," says Michael Manga from University of California, Berkeley, who took part in the study. "We're saying that the oceans predate and accompany the lava outpourings that made Tharsis."

The mineral composition and topography of Mars suggest that there was once a huge ocean covering its northern hemisphere. However, several key questions that challenge this theory remain, such as what happened to all the water? And why is the supposed shoreline not level?

The first of these issues is caused by current estimates for the oceans' volume, which are too large. If there had been as much water on Mars as currently predicted, it would not have had time to completely evaporate into space or freeze into permafrost. However, these estimates are based on the current landscape, which is deformed by the Tharsis region. If the oceans had formed before or at the same time as the volcanic structure, they would have been much shallower.

The new simulations could also explain why the geological features thought to be the ancient shoreline are uneven. On Earth, shorelines are all at sea level, but those on Mars vary in elevation. But if the ocean and its coast formed when Tharsis was young, the landscape would have changed as the region grew, deforming the shoreline in the process.

"These shorelines could have been put in place by a large body of liquid water that existed before and during the emplacement of Tharsis, instead of afterwards," says University of California, Berkeley graduate Robert Citron, who led the study.

The current work is all theoretical, but the InSight lander heading to Mars this month could help test the concept by mapping the Martian interior and examining the planet's volcanic past.

"This is a hypothesis," stresses Manga about the study's findings. "But scientists can do more precise dating of Tharsis and the shorelines to see if it holds up."

https://www.berkeley.edu/

▸ **Read more about InSight on page 32**

Galaxy lacks dark matter

Astronomers have found a galaxy that appears to be completely empty of Dark Matter.

"Finding a galaxy without dark matter is unexpected because this invisible, mysterious substance is the most dominant aspect of any galaxy," says Pieter van Dokkum from Yale University, who published a study on the galaxy in March. "For decades we thought galaxies start their lives as blobs of dark matter. NGC 1052-DF2 challenges the standard ideas of how we think galaxies form."

▲ NGC 1052-DF2 is confounding accepted ideas of galaxy formation

Astronomers calculated the mass of the galaxy using the Keck telescope to measure the speed of the stars in the system. They found that this mass could be entirely accounted for by the stars in the galaxy, leaving no room for dark matter.

"There is no theory that predicted these types of galaxies," says van Dokkum. "How you actually go about forming one of these things is completely unknown. The galaxy is a complete mystery as everything about it is strange. "
http://www.keckobservatory.org

UK passes new space laws

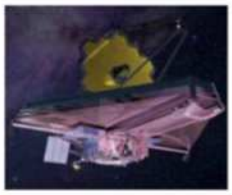
Legislation allows for launches in Britain and a space port could follow

The Space Industry Bill was given Royal Assent and passed into law on 15 March, opening up the UK space sector for more innovation and investment. The Bill will allow the first commercial space launch from UK soil, paving the way for the creation of a new spaceport. A British launch platform would create hundreds of new jobs and generate billions of pounds for the UK economy, according to a government study.

"This Bill offers an exciting opportunity for the UK to soar to new heights and be at the forefront of the commercial space age," says Sam Gyimah, UK Minister for Universities, Science, Research and Innovation. "We will set out how we plan to accelerate the development of the first commercial launch services from the UK, and realise the full potential of this enabling legislation over the coming months."
www.gov.uk

Newquay in Cornwall is one of the locations in the running to be home to the UK's first space port

NEWS IN BRIEF



JWST PUSHED BACK TO 2020

NASA has announced that the launch of the James Webb Space Telescope has been pushed back from 2019 to May 2020. Several issues caused the delay, notably the sunshield taking longer than planned to assemble and leaks in the propulsion system. "Considering the investment, we want to proceed systematically through these last tests with the additional time necessary," says Thomas Zurbuchen, associate administrator for NASA's Science Mission Directorate.

'OUMUAMUA FROM A BINARY

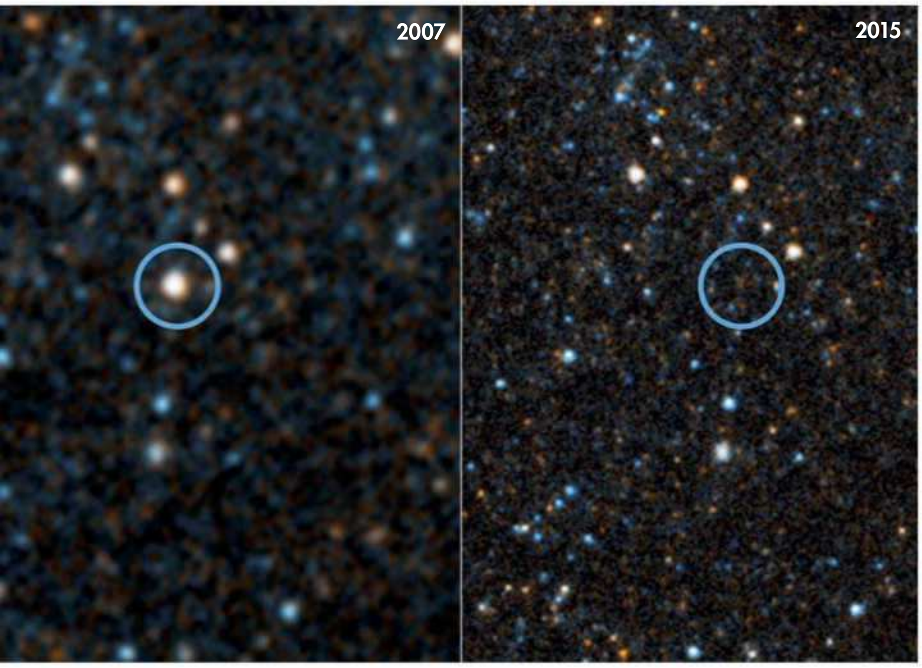
'Oumuamua, the asteroid that passed through the Solar System in October 2017, was probably thrown out into deep space from a binary star system. A new study by University of Toronto Scarborough's Alan Jackson shows that binary star systems eject rocky bodies from orbit, while single star systems like our own hurl out more icy ones. The 200m-long asteroid probably started life around a hot, high-mass star, but was thrown out during the formation of its planets.

CUTTING EDGE

Our experts examine the hottest new research

Black Holes that may not have explosive origins

Most black holes start their life in a supernova, but there are some that have much quieter origins



▲ **N6946-BH1 before and after: in 2009 it flared to over a million times brighter than the Sun then imploded into a black hole**

NASA/ESA AND C. KOCHANEK (OSU)

Some stars, it seems, end their lives not with a bang, but with a whimper. When large stars – specifically those greater than about eight solar masses in size – run out of hydrogen at their core, they are unable to support themselves through nuclear fusion and they collapse. The result is a dramatic explosion which we all know as a supernova. That's the process at its most basic. But the details are tricky.

Depending on the precise mass of the exploding star – and on the physics of the collapse – the result might be a neutron star, a black hole, or the total destruction of the star leaving no compact remnant behind at all. Stars that are only just big enough to go bang are believed to suffer the latter fate, producing supernovae but not black holes.

We do need a way to explain the creation of low mass black holes, though, and astronomers are on the case. They've been looking for stars that just seem to disappear without fuss, ending their lives without a supernova, instead collapsing directly into a black hole. The first – and so far only serious – candidate for such an event is a star called N6946-BH1 in a galaxy called NGC 6946, which is about 18 million lightyears away.

N6946-BH1 was once a massive red supergiant like Betelgeuse and Antares, but in 2009 it briefly brightened and then faded away. Since then it's been mostly visible in the infrared range, but even on this wavelength it is now gradually fading away. This infrared emission is believed to come from dust in the ejected outer envelopes of the star, with the central parts having collapsed to form a black hole.

Understanding this system could therefore give us clues as to how black holes form, but studying it is difficult without knowing more about the progenitor star. Instead, a team of US-based astronomers has been looking hard at its neighbourhood. The idea is that other, nearby stars offer easy ways to work out the age of a population. You can study what's called the main sequence turnoff, for example: the luminosity above which all the stars have stopped 'burning' hydrogen in their cores. Or you can look at easy-to-understand, helium burning stars and use them to calculate how recently star formation has been taking place.

"This infrared emission is believed to come from dust in the ejected outer envelope of the star, with the central parts having collapsed to form a black hole"

When they bring all the tools of modern stellar astrophysics to bear on the problem, they find that the last great burst of star formation in the region happened about 10.5 million years ago. So, making what seems a reasonable assumption that N6946-BH1 hasn't just wandered in from some other region of space completely, that means 10.5 million years is how old it is likely to be as well. If it *is* that old, and it just reached the end of its life, it must have had a mass of about 18 times that of the Sun.

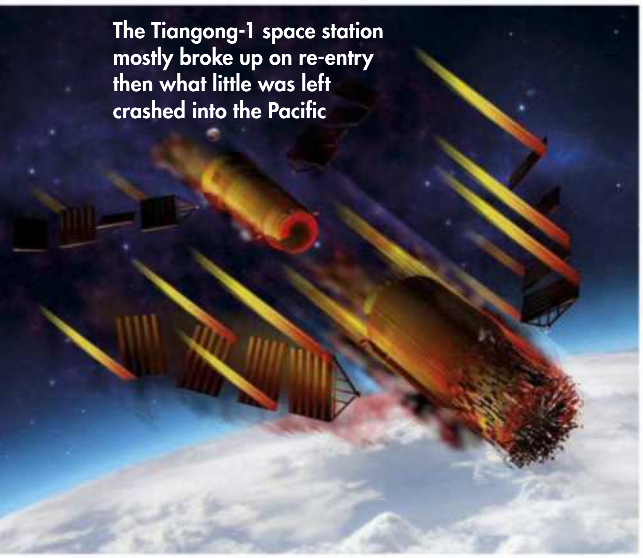
Assuming that's right, we now know of one kind of star capable of producing, quietly, a black hole at the end of its life. The errors on the measurement are large though, and there's not much more to be done, other than keep a close eye on nearer galaxies to see whether they too harbour vanishing stars.

CHRIS LINTOTT is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also the director of the Zooniverse project

CHRIS LINTOTT was reading… *The Progenitor Age and Mass of the Black-Hole-Formation Candidate N6946-BH1* by Jeremiah W Murphy et al. **Read it online at https://arxiv.org/abs/1803.00024**

Chinese space station crashes back

CNSA's first orbital outpost had been out of control since 2016



The Tiangong-1 space station mostly broke up on re-entry then what little was left crashed into the Pacific

After re-entering the atmosphere at 00:15 UT, the Tiangong-1 space station crashed into the southern Pacific Ocean on 2 April.

The Chinese National Space Administration (CNSA) lost control of the spacecraft after an unspecified fault developed in 2016 and it began to lose altitude. Though the entry was uncontrolled, meaning that Tiangong-1, which was the size of a small bus, could have crashed down in a populated area, there was little risk to life as the station mostly burned up in the atmosphere.

Tiangong-1 (meaning Heavenly Place-1) was China's first step towards creating a permanent human base in space but it was only ever intended to be temporary. A second test station, Tiangong-2, was launched on 15 September 2016 and a permanent base is expected some time in the next few years.

http://www.cnsa.gov.cn

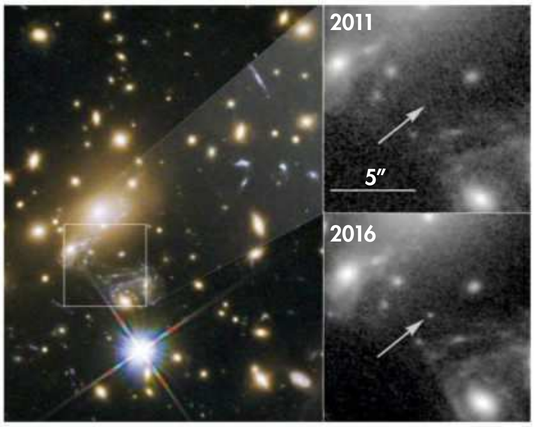
Most distant star ever spotted

The furthest individual star ever seen has been discovered in recent Hubble images, thanks to a naturally occurring gravitational quirk.

The light from the star, nicknamed Icarus, has taken nine billion years to reach us, and dates from when the Universe was four billion years old. The gravity of a galaxy cluster bent Icarus's light, magnifying it by 2,000 times – a process known as gravitational lensing – making it visible.

"This is the first time we're seeing a magnified, individual star," says Patrick Kelly of the University of Minnesota, Twin Cities, who led the study. "You can see individual galaxies out there but this star is at least 100 times further away than the next individual star we can study, except for supernova explosions."

http://hubblesite.org



▲ Hubble was monitoring a supernova in a distant spiral galaxy when, in 2016, it detected a new point of light

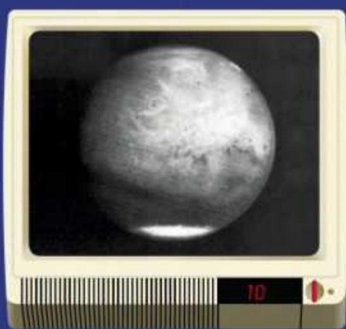
LOOKING BACK THE SKY AT NIGHT

19 May 1969

On 19 May 1969, Patrick Moore and *The Sky at Night* looked towards the Red Planet in anticipation of the Mariner 6 and 7 flybys that were due to happen a few months later. The twin spacecraft would provide a close view of the planet, as planetary scientists hoped to answer one of the biggest questions surrounding the world – is there life on Mars?

Until that point people believed that complex life, and perhaps even intelligent civilisations, might exist on the Martian surface. The latter idea originated with the observations of Italian astronomer Giovanni Schiaparelli who, in 1887, mapped dark areas on Mars. A mistranslation of his work led to the popular belief that these were canals, possibly built by a highly advanced civilisation.

However, when Mariner 6 and 7 sent back their images, they found no signs of any canals, or a race that might have built them.



▲ Mariners 6 and 7 debunked the idea that there were canals on Mars

NEWS IN BRIEF

DESTROYING ASTEROIDS

In a case of movie science made real, a team of planetary geologists has proved that you really would be able to destroy a life-threatening asteroid with a nuclear bomb. In an experiment, the team created miniature asteroids with the same physical characteristics as the meteor that exploded over the town of Chelyabinsk in 2013. They simulated a nuclear explosion using lasers, discovering that a three-megaton bomb could eliminate a 200m sized asteroid.

BIG BUDGET FOR NASA

NASA was granted a budget $1.6 billion larger than it requested from Congress on 23 March. The extra funding will go towards building a new mobile launch platform for the Space Launch System, as well as allowing work on a future lander mission to Jupiter's icy moon Europa. The new budget also keeps several Earth science and educational initiatives that the Trump administration (a different branch of government to Congress) was seeking to cancel.

ALEJANDRO MIRANDA/ALAMY STOCK PHOTO, NASA/ESA AND P. KELLY (UNIVERSITY OF MINNESOTA), NASA/JPL, NASA/JPL-CALTECH/UMD, NASA

CUTTING EDGE

Our experts examine the hottest new research

Counting craters

Machine learning could help researchers date planetary surfaces by tallying up their craters

NASA

▲ **Counting craters by eye is easy for the big ones, but we may need to use AI to include smaller ones**

Counting the number of craters in a region of a planetary surface gives scientists important information on how old the planet is. Like specks of raindrops accumulating on a pavement, the longer a surface has been exposed, the more craters it will have. Crater densities tell you the relative age of features like lava flows or wind deposits, and if we've also been able to analyse a sample from the surface (as we have with lunar rocks returned by the Apollo programme and then dated precisely by measuring radioactive isotopes, for example), we can then also calculate the absolute age of whole regions.

The problem is that crater counting has traditionally been an exceedingly slow and laborious exercise; up until now it's been mostly done by human eye. The data we've been able to gather this way either covers large areas of a surface taking note of only the largest craters, or it includes the smaller craters but covers only a very specific, limited geographic region. Automated methods using computer algorithms have been developed, but they can often be confused by overlapping or degraded craters, variations in illumination or other landscape features, such as ridges.

Ari Silburt at the University of Toronto and his colleagues have been trying to change all of this. They have applied a new computer technique to the challenge based on Deep Learning, which uses artificial neural networks, where the computer emulates the functioning of a simple brain. As Silburt himself explains, "Similar to how a human learns to recognise a cat by seeing many different examples of cats, a computer can learn to recognise a cat via machine learning by receiving many examples of what is and isn't a cat."

Silburt and his team applied their neural network to landscape maps of the Moon's surface created by the Lunar Reconnaissance Orbiter and Kaguya probes. The immediate advantage of starting with these 'digital elevation maps', rather than simply photographs, is that they are not affected by varying shadows from different angles of sunlight.

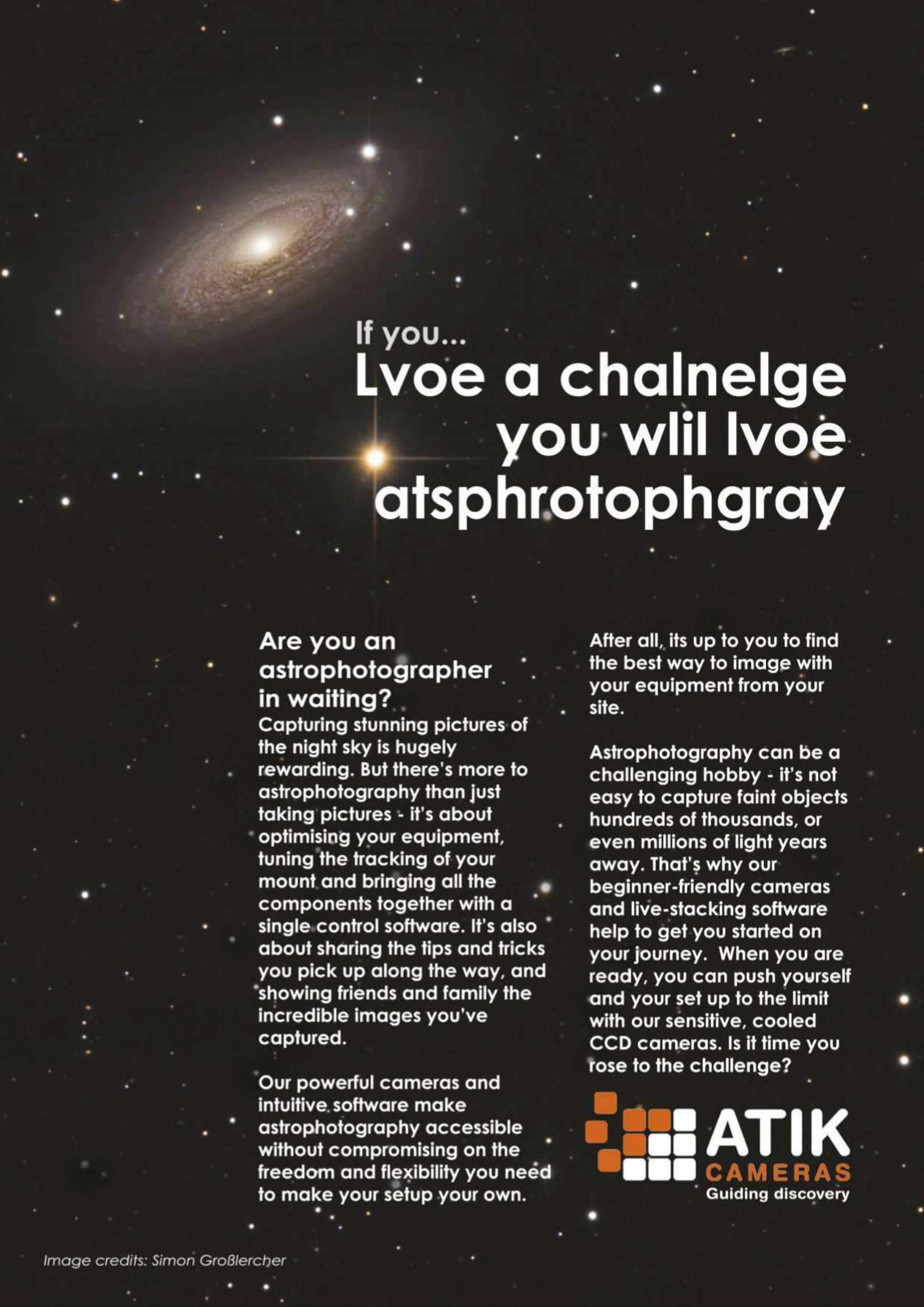
They first tested their neural network on images that had already been counted by scientists to check that it worked reliably. Their technique successfully located 92 per cent of the craters identified by the human experts. Crucially, it also found a large number of new craters – almost twice as many, in fact, and in particular scores of those very small craters that are often neglected in crater counts carried out with the human eye. Silburt then applied his neural network to the planet Mercury and found that his technique also worked very well on this completely different terrain.

"Their technique located 92 per cent of the craters identified by experts. It also found a large number of new craters"

While this is a very promising new approach, Silburt's crater-counting computer code still had an error rate of about 11 per cent. This isn't too bad, but probably not quite good enough just yet to be used for completely automating the process of building accurate crater catalogues. Silburt and his team are now working on tweaking and perfecting their system. Nevertheless, this represents a very promising approach for automating the laborious process of identifying the number and sizes of craters, and so ultimately improving our understanding of how different landscapes on planets in the Solar System formed.

LEWIS DARTNELL is an astrobiology researcher at the University of Westminster and the author of *The Knowledge: How to Rebuild our World from Scratch* (www.the-knowledge.org)

LEWIS DARTNELL was reading… *Lunar Crater Identification via Deep Learning* by Ari Silburt et al
Read it online at https://arxiv.org/abs/1803.02192


If you...
Lvoe a chalnelge you wlil lvoe atsphrotophgray
Are you an astrophotographer in waiting?
Capturing stunning pictures of the night sky is hugely rewarding. But there's more to astrophotography than just taking pictures - it's about optimising your equipment, tuning the tracking of your mount and bringing all the components together with a single control software. It's also about sharing the tips and tricks you pick up along the way, and showing friends and family the incredible images you've captured.
Our powerful cameras and intuitive software make astrophotography accessible without compromising on the freedom and flexibility you need to make your setup your own.
After all, its up to you to find the best way to image with your equipment from your site.
Astrophotography can be a challenging hobby - it's not easy to capture faint objects hundreds of thousands, or even millions of light years away. That's why our beginner-friendly cameras and live-stacking software help to get you started on your journey. When you are ready, you can push yourself and your set up to the limit with our sensitive, cooled CCD cameras. Is it time you rose to the challenge?
ATIK CAMERAS
Guiding discovery
Image credits: Simon Großlercher

“The Orion Nebula and the Pillars of Creation - the Eagle Nebula” from the “Starscape – Out of this world” series

Details of other paintings in this series look in The Gallery at

www.galweyartworks.co.uk

What's on

Our pick of the best events from around the UK

Festival of Science: Space

Royal Albert Hall, London, 5 May–10 July

The first of a new series of science festivals taking place at the Royal Albert Hall kicks off this month, beginning with an exploration of the Universe around us. With events taking place up until July, Festival of Science: Space has a packed programme filled with talks, live music, theatre, film screenings and events suitable for young and old.

Enjoy a 'Space Spectacular' with the Royal Philharmonic Orchestra, performing the music of Holst, Strauss and John Williams, and hear a live recital of music by the 18th century astronomer Sir William Herschel.

Find out about the exploration of Mars from Prof David Southwood and Prof Sanjeev Gupta, and learn about the Cassini mission to Saturn from Prof Michele Dougherty, Principal Investigator for the spacecraft's magnetometer.

Join astronaut Chris Hadfield and *The Infinite Monkey Cage* host Robin Ince for an evening of science, music and comedy in Space Shambles, and discover the science behind some famous sci-fi films with astrophysicist Dr Roberto Trotta.

Shows aimed at children and young people include a celebration of Albert Einstein; the Ensonglopedia of Science; an imaginary intergalactic trip in A Strange New Space; and a space-themed orchestral adventure.

For the full programme and tickets visit the Royal Albert Hall's website.
www.royalalberthall.com

BEHIND THE SCENES

THE SKY AT NIGHT IN MAY

BBC Four, **13 May,** 10pm (first repeat BBC Four, **17 May,** 7.30pm)*

Gaia is expected to discover hundreds of thousands of new celestial objects

A GALACTIC REVOLUTION

The Gaia mission is a project headed by the European Space Agency to make a 3D map of the Galaxy by studying over a thousand million stars. Following Gaia's second data release, Chris and Maggie find out what we've learned and what it might reveal about the formation and evolution of our Galaxy.

**Check www.bbc.co.uk/skyatnight for subsequent repeat times*

Eta Aquariids meteor shower

The Observatory Science Centre, Herstmonceux
5 May, 8pm

View the night sky through some of the largest telescopes in the country (weather permitting). This event coincides with the Eta Aquariids meteor shower, which will be nearing its peak on the night. Experts will be on hand to answer your questions and in the event of poor weather there will be a planetarium-style presentation. For more information visit the observatory website.
www.the-observatory.org

Observatory open evening

St Andrews Observatory, University of St Andrews
2 May, 7pm

Get up close with the James Gregory Telescope, the largest working optical telescope in the UK. This open evening includes an astronomy-related presentation revealing the history of the scope – a 37-inch instrument that has been in operation for 50 years – plus the chance to see it in action and put your cosmic questions to a resident astronomer. This monthly event is free and open to the public.
www.observatory.wp.st-andrews.ac.uk

Appley Bridge Meteorite

Llanrhos Old School, Llandudno, Conwy
23 May, 7.30pm

The Appley Bridge meteorite crashed to Earth in 1914, landing in rural Lancashire and causing quite a stir at the outbreak of the First World War. Russell Parry, author and expert on the meteorite, details the story for the North Wales Astronomy Society. Plus, take your telescope along for help and advice from the society's members. Admission is £1 for members and £3 for non-members.
www.northwalesastro.co.uk

MORE LISTINGS ONLINE

Visit our website at **www.skyatnightmagazine.com/whats-on** for the full list of this month's events from around the country.

To ensure that your talks, observing evenings and star parties are included, please submit your event by filling in the submission form at the bottom of the web page.

ROYAL ALBERT HALL, OBSERVATORY SCIENCE CENTRE, FIONA CONN, ESA/ATG MEDIALAB; BACKGROUND: ESO/S BRUNIER

A PASSION FOR SPACE

with **Dr Sanjeev Gupta**

The Curiosity rover has been on Mars over 2,000 sols now but its biggest revelations may be still to come

The Vera Rubin Ridge looks deceptively Earth-like, but its remarkable rocks have a hidden tale to tell

Sitting atop the Vera Rubin Ridge in Gale crater, Curiosity rover has just celebrated two major milestones. It has now been exploring the Red Planet for 2,000 sols – or Martian days – having traversed 18.7km since August 2012. Which also means it's been on the planet for three Martian years.

From this vantage point, Curiosity's science team has enjoyed some remarkable panoramic images thanks to the rover's Mastcam cameras. For those of us familiar with deserts from fieldwork, they have a weird Earthly quality, with hills and mountain slopes of stratified sedimentary rocks that resemble what you might find in North Africa. But scattered here and there are those tell-tale signatures of a different world: impact craters, holes gouged into the surface by colliding meteorites.

Curiosity's mission to Mars is first and foremost an exploration of habitability; to assess the Martian surface as a potential habitat for past or present life. Our focus is the ancient rock successions preserved in Gale crater that hail back to a time when

NASA/JPL-CALTECH/MSSS X 2

Martian mudstones found at the base of Mount Sharp in Gale crater

Mars's climate may have been more hospitable to microbial life than today's harsh conditions. This is where my own speciality comes into play.

Written in the rocks

I am a sedimentary geologist. Through clues in rocks, I can tell you what a landscape looked like millions, if not billions, of years ago. But I never imagined I would be doing this on Mars.

Curiosity's travels in Gale crater have revealed a spectacular array of sedimentary rocks which attest to dynamic ancient environments. Rivers derived from the crater rim built alluvial fans composed of rounded pebble beds and small underwater dunes. These rivers eventually built a series of deltas that fed water and sediment into a lake that the science team believes filled the centre of the crater. Lake deposits are brilliant for astrobiology. They not only represent quiet-water environments with good potential for the development of microbial life, but they also increase the chances of preserved evidence.

Preservation is a crucial factor. Life may have been present, but its traces erased by billions of years on the surface of Mars. In Gale crater we found remarkable mudstones made up of millimetre-thick layers – laminations – that record the settling of fine-grained sediment in a standing body of water. We've driven across hundreds of metres of such laminated mudstones, which suggests that this lake existed for hundreds of thousands, if not millions, of years.

The rocks that make up the Vera Rubin Ridge are also finely laminated mudstones but with an abundance of the iron oxide, haematite. We knew about the haematite from orbital observations, but not how it came to be. Was it related to the chemistry of the lake water? Was it caused later by fluids percolating through the rocks? And what implications does it have for possible life on ancient Mars? The Curiosity science team is grappling with these problems at this very minute. Watch this space!

Dr Sanjeev Gupta is a co-investigator on the Curiosity rover's Mastcam team

Maggie Aderin-Pocock is on holiday


— WINNER —
MIND-BLOWING SPECTACLE
★★★★★
UK FESTIVAL CONGRESS
bluedot
— WINNER —
NEW FESTIVAL ON THE BLOCK
★★★★★
UK FESTIVAL CONGRESS
JODRELL BANK OBSERVATORY. CHESHIRE. EARTH.
19.20.21.22 JULY 2018
DOT TALKS FROM LEADING SCIENTISTS & THINKERS
ALICE ROBERTS. JIM AL-KHALILI.
LIBBY JACKSON. DALLAS CAMPBELL.
TIM O'BRIEN. TERESA ANDERSON MBE.
SUZIE IMBER. ALICE ELDRIDGE.
TAMSIN EDWARDS. DAVE GOULSON.
FULL SPEAKER LINE-UP STILL TO BE ANNOUNCED.
LIVE MUSIC ACROSS 3 STAGES
THE CHEMICAL BROTHERS
THE FLAMING LIPS. FUTURE ISLANDS
THE BLUE PLANET IN CONCERT WITH THE HALLÉ*
PUBLIC SERVICE BROADCASTING. GARY NUMAN. LITTLE DRAGON. SLOWDIVE. UNKLE. RONI SIZE: NEW FORMS LIVE.
GILLES PETERSON. BOOKA SHADE. THE ORB. GEORGE FITZGERALD [LIVE]. LAMB. ALEXIS TAYLOR. NADINE SHAH.
CRAZY P [LIVE]. ADRIAN SHERWOOD. HOOKWORMS. BALOJI. VESSELS. AFRIQUOI. ACID MOTHERS TEMPLE.
CRAIG CHARLES' SPACE FUNK ODYSSEY. LOST HORIZONS. BUGGED OUT TAKEOVER. + MANY MORE
COMEDY
DAVID O'DOHERTY. CASSETTEBOY. ROBIN INCE. ROB KEMP: THE ELVIS DEAD.
SIMON MUNNERY. GARY DELANEY. JESS FOSTEKEW.
STILL TO BE ANNOUNCED
ARTS & CULTURE. LATE NIGHT MISSION CONTROL DJS. ROOTS STAGE. THE OUTER SPACE ARTS ARENA.
LOVELL TELESCOPE INSTALLATION. WELLNESS AREA. THE STAR FIELD. THE PLANET FIELD. SCIENCE WORKSHOPS.
KIDS ACTIVITIES. G'ASTRONOMY AND REAL ALE. STARGAZING.
+ MUCH MORE.
WEEKEND CAMPING FROM £169
DISCOVERTHEBLUEDOT.COM
CRACK
Sky at Night
FOCUS
CITYLIFE
FROM THE FIELDS
CURATED BY
FROM THE FIELDS & THE UNIVERSITY OF MANCHESTER
*REQUIRES ADDITIONAL THURSDAY TICKET

JON CULSHAW'S

EXOPLANET EXCURSIONS

Jon pilots the Perihelion to a hot, wet gas giant with coffee-coloured bands

Seven hundred lightyears away, in the constellation of Virgo, lies a faint star with the name Wasp-39. It shines faintly in our skies with a magnitude of +12.1 – within the grasp of a large telescope set up under dark skies. Wasp-39 is a G8-class, yellow dwarf star very similar to our own Sun, being 93 per cent of its mass and about 90 per cent of its radius. It's far enough away that the light from it reaching us now began its journey around the time of the Battle of Bannockburn in the early 1300s!

I'm on the way to Wasp-39 in my ship the Perihelion, to take a closer look at a recently discovered gas giant in a very close orbit to the star. Wasp-39b is about the size of Saturn, and it's just 0.05 AU from Wasp-39; that's 20 times closer than Earth is to the Sun. Such a close orbit – taking just four days to complete – leaves Wasp-39b tidally locked, with the star-facing side baking at a blisteringly hot 776°C. Powerful, fast winds distribute this heat evenly all the way around its atmosphere. It's likely that Wasp-39b formed much further out in the system and – like that other class of gas giant exoplanets, 'hot Jupiters' – migrated in to its current position at some point in its past.

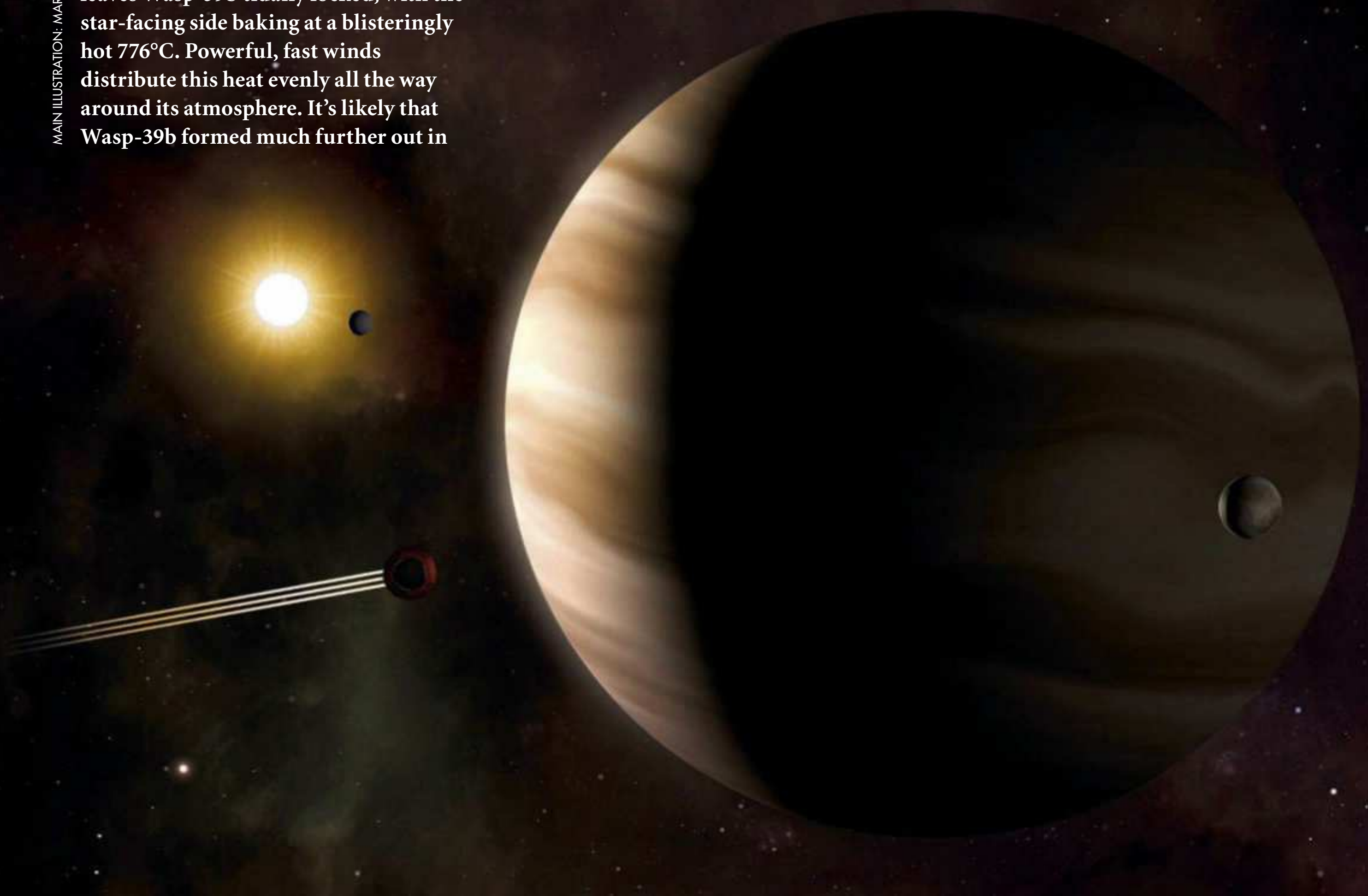
Wasp-39b has been described as a 'wet gas giant', however, because water has been detected in its atmosphere; water that may well have come from collisions with comets and other bodies earlier in its history. Spectra taken with the Hubble and Spitzer Space Telescopes discovered the presence of huge amounts of water in the upper atmosphere; in fact, three times as much water as exists on Saturn. This is certainly a most curious prospect.

I wonder what sounds might be created by a world described as a 'wet gas giant'. The sloshing and gurgling of a planetary-grade orbiting laundrette? Perhaps combined with the eerily evocative sound of shortwave radio signals or Morse code, and the mating call of a Megalodon? It's a whimsical idea at least, a part of the Universe that could well have been conjured up by Douglas Adams.

Stopping the Perihelion 1.2 million km from the planet – the same distance that Titan orbits Saturn – I am rewarded with an arresting view of Wasp-39b. It has the gentle appearance of a vanilla-flavoured gas giant, garlanded with coffee-coloured parallel shades of beige and off-white, but I bet it smells of hot Brasso.

We're familiar with Jupiter's shades of ochre, steel blue and silvery white. The texture of Wasp-39b's atmosphere follows similar if much softer patterns, with curves and swirls of more delicate shades. The bands appear as though they could have been made by a creative barista using the soft hues of a Dulux colour chart.

Jon Culshaw is a comedian, impressionist and guest on *The Sky at Night*



MAIN ILLUSTRATION: MARK GARLICK, SPACECRAFT: PAUL WOOTTON, PHOTO: EMMA SAMMS

Interactive

EMAILS ◢ LETTERS ◢ TWEETS ◢ FACEBOOK

Email us at **inbox@skyatnightmagazine.com**

This month's top prize: four Philip's books

PHILIP'S The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Mark Thompson's *Stargazing with Mark Thompson* and Heather Couper and Nigel Henbest's *2018 Stargazing*.

MESSAGE OF THE MONTH

A sight for naked eyes

You don't need extra lenses to admire Orion's celestial splendour

I did enjoy reading the January edition of *BBC Sky at Night Magazine*, particularly Will Gater's 'Capturing the Hunter' feature on Orion – a constellation that has been a favourite of mine for years. I'm in my 70s and have neither telescope nor binoculars, so all my sky watching is naked-eye. The other night I was lucky enough to see a huge shooting star going through Orion, just above his Belt. Also, on the left-hand side of Orion's Belt, I could see something that looked like a cluster of small star-like objects. I have heard of the Horsehead Nebula but am not sure where it is – could it be the small cluster I saw?

Lastly, can I share with you a sight that I felt extremely lucky to see one crisp late-autumn morning while I was walking with my dog? I looked up to see, on my right, the crater-pocked Moon still high in the sky. To my left, the rising Sun was a ball of fire, while I stood watching, mesmerised, on planet Earth.

Christine Rae, Dalry

What a powerful picture you paint, Christine! The Horsehead Nebula is just south of the left-most star in Orion's Belt, but unfortunately it's impossible to see with the naked eye. **– Ed**

A new infant star

Just a quick message to say that we really enjoy the magazine and to show that you have a new reader in our seven-month-old son, Evan. He loves looking at the photos and hopefully he too will grow up to appreciate the wonder of the Universe. We love this photo!

Richard & Vanessa Baker, Rotherham

Thanks for the photo: it is wonderful to see the mag raise such a smile! **– Ed**

Astral art

I have subscribed to your magazine for many years and thoroughly enjoy it. I thought you might like to see two watercolour paintings I finished recently, one of Jupiter and the other of the Orion Nebula, both of them based on pictures from *Sky at Night Magazine*. My art tutor suggested that I send them to you. I hope you like them!

Trudi Sealey, via email

Two tricky subjects to paint, but you've done a remarkable job, Trudi. **– Ed**

◂ You don't get landscapes like this on *Watercolour Challenge*

Tales from THE EYEPIECE

Stories and strange tales from the world of amateur astronomy by Jonathan Powell

"Several months ago I spent a long time queuing behind an elderly gentleman at a car park pay and display machine, only to discover he was only interested in how the machine worked and didn't actually want to buy a ticket! Like the machine, I too have experienced inquisitive staring from strangers while out observing, but I've never pretended to stargaze as an excuse. Once while out driving at night, my brother was stopped by the police and asked what he was doing. Thinking of me, he replied he was an astronomer looking for an observing location. He was expecting a barrage of questions or sarcasm, but the officers were pleased at his honourable leisure time pursuit and sent him on his way. May the force be with you!"

Email your own tales to Jon at TalesfromtheEyepiece@themoon.co.uk

Jonathan Powell is the astronomy correspondent for the *South Wales Argus*

ISTOCK

SOCIETY in focus

▲ **Star parties at Swansea Airport help spread the word about astronomy**

Swansea Astronomical Society's biggest outreach is through our star parties. At present we use three venues: the National Waterfront Museum in Swansea, the National Botanical Gardens of Wales in Carmarthenshire and Swansea Airport. Yes, I did say Swansea Airport – I'll come back to that in a moment.

The first two make good venues because of their locations and facilities. They offer excellent outdoor space for observation as well as indoor areas for talks, shows and telescope clinics… as well as somewhere to retreat to if conditions are cloudy or wet. This brings us to our third and most unlikely venue: Swansea Airport.

Opened as RAF Fairwood Common in 1941, the airport was the base for Hawker Hurricane day fighter squadrons along with a night fighter squadron of Bristol Beaufighters for the duration of World War II. Since its decommissioning in 1949 it has had a chequered life. It has seen regular passenger services to Jersey, been host to a number of historical aircraft and also been home to a squadron of the Air Cadets Gliding School. There is no night flying nowadays, which would have prevented us using the site, but it is used by both the Swansea Skydiving Club and Cambrian Flying Club.

The site is extremely dark as it's located on the Gower Peninsular, Britain's first designated Area of Outstanding Beauty. Most of the surrounding land is also a Special Area of Conservation.

Though the airport has accessible toilets it does not currently have any refreshment facilities apart from a vending machine. There is a café but we use this for our talks, while the waiting area and corridors are used for displays and our telescope clinic. Recent cancellations of our events at the venue – as happened in March this year – are making us reconsider its suitability for future star parties, but we will have to wait and see. Watch this space!

www.classroominspace.org.uk

Phillip John, Assistant Treasurer, Swansea Astronomical Society

Tweets

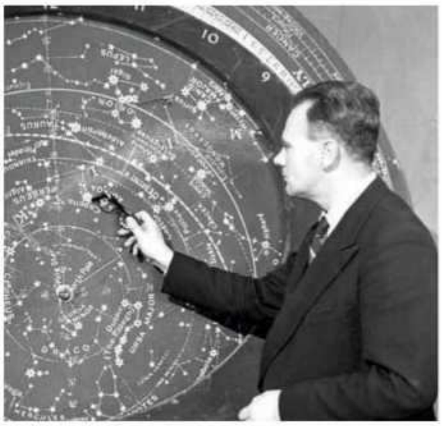
Austin Taylor
@aurorashetland • Mar 20
Last night's amazing show, with #STEVE and #aurora at Lerwick, Shetland #aurorashetland #shetlandastronomy @TamithaSkov @aurorawatchuk @AWUK_Shetland @VirtualAstro @ProfBrianCox @skyatnightmag

The fate of a TV icon

I am an amateur astronomer and member of Salford Astronomical Society with a great interest in the history of astronomy. After a recent talk by our chairman, Dr Allan Chapman, we got talking about the location of the giant planisphere that was used as the background on the *Sky at Night* programme in its early years. I wondered if it was still kept in storage somewhere, or has it ceased to exist?

Gary Yule, via email

Although Patrick's observing notebooks, along with some of his telescopes and other effects, are kept by the Science Museum, the original giant planisphere was disposed of around 1968, after more than a decade's use as scenery on The Sky at Night. *A reproduction was made for the show's 50th anniversary, and this is currently in our possession on the magazine.* ***– Ed***



▲ **Patrick Moore points to Capella on *The Sky at Night* TV series' iconic planisphere in 1960**

Tweets

Tom
@TomWelland • Mar 23
Spent a nice evening with a clear sky in Sullington Warren.

Meanwhile on FACEBOOK…

WE ASKED: What do you think has been Professor Stephen Hawking's greatest contribution to humanity?

Danny CAstro
Himself. He's an inspiration and a great example that no matter what life throws at you, you can make the most out of any situation you find yourself in no matter how bad. Thanks for your contribution to science, Professor.

Andy Hearns
Advocating for science. Powering through illness. Thinking big when the world seems to be getting more insular.

Malcolm Haswell
You've just got to respect his sheer bloody-mindedness and humour. He was a leading opponent of Fred Hoyle's Steady State Theory at a time Fred (a true genius himself) was at the height of his powers at Cambridge. He demonstrated how important an active and lively mind were/are to individuals and those around them. He's appeared on more popular programmes like *The Simpsons* and *The Big Bang Theory* than most other scientists and apparently had a wicked sense of humour.

Youdhisthir Rai
I think he always wanted us to travel the stars.

Sophie Jenkins-Jones
He focused on the 'can do', rather than the 'can't do'. Fantastic message to us all.

Tony Moss
He inspired lots of us less academic people to become interested in science.

Wayne Ryles
He encouraged people to think big despite whatever illness or problems you might have.

Kari Brown
He showed a diagnosis is not a sentence and that it really is possible to do what you love regardless what other people say!

Hotshots

This month's pick of your very best astrophotos

YOUR BONUS CONTENT

A gallery containing these and more of your stunning images

▲ Comet C/2016 R2 (PANSTARRS) & the Pleiades

JOSÉ J CHAMBÓ, NEW MEXICO, US, 4 FEBRUARY 2018

José says: "The comet deploys a long, blue tail inside our Solar System, composed of carbon monoxide ionised by the solar wind, while the blue nebulosity around the star cluster is clouds of interstellar dust enlightened by the brightest stars.

The image is a mosaic composed of three tiles, to fill a wide field of 7°x2° and catch both the comet and Pleiades. The main difficulty was balancing the processing so that I could highlight the faint comet without overexposing the bright cluster."

Equipment: SBIG STL11000M CCD camera, Takahashi FSQ-106ED refractor.

***BBC Sky at Night Magazine* says:** "We're already well aware of José's incredible comet images, but this one really made us take notice. Managing to capture both the comet and the Pleiades is a real treat, creating one of those images that, the longer you look at it, the more detail leaps out at you."

About José: "I started to develop as an amateur astronomer in 1985 during the last visit of Halley's Comet. I have been enthusiastic about comets from the beginning, and in all these years I have extended my knowledge and experience in tracking and observation, as well as in astrophotograpy. My advice to beginners would be to specialise in a specific genre of astrophotography that interests them. Look at the work of the best photographers but discover your own style and always try to improve."

◀ Loch Ness star trails

DAVID WEIGHTMAN, LOCH NESS, 13 FEBRUARY 2018

David says: "On a recent work trip, I wanted to take the opportunity afforded by Scotland's dark skies. I tried a few different compositions but this was by far my favourite; you can just make out the Winter Triangle with a hint of the Milky Way running through the middle."

Equipment: Pentax K-r DSLR camera, Sigma 17-35mm lens.

▲ Craters Aristoteles & Eudoxus

AVANI SOARES, CANOAS, BRAZIL, 25 DECEMBER 2018

Avani says: "Some things are essential to obtain a good astro image; among them seeing, acclimatisation, collimation and focus. The first, in my opinion, is the most important, but unfortunately there is nothing we can do to improve it other than waiting for a good night!"

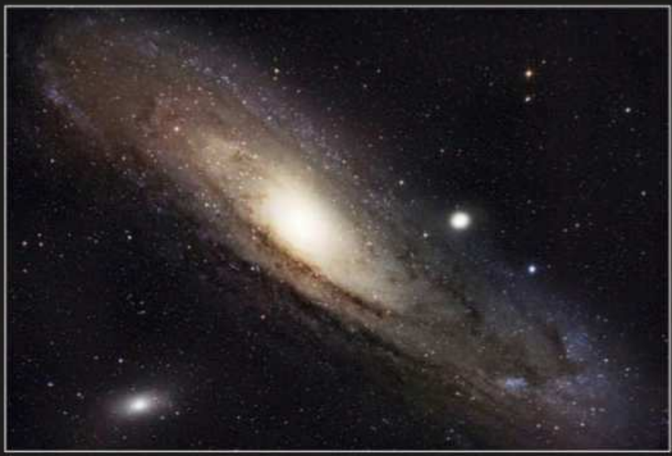
Equipment: ZWO ASI 290MM, Celestron EdgeHD 14 Schmidt-Cassegrain.

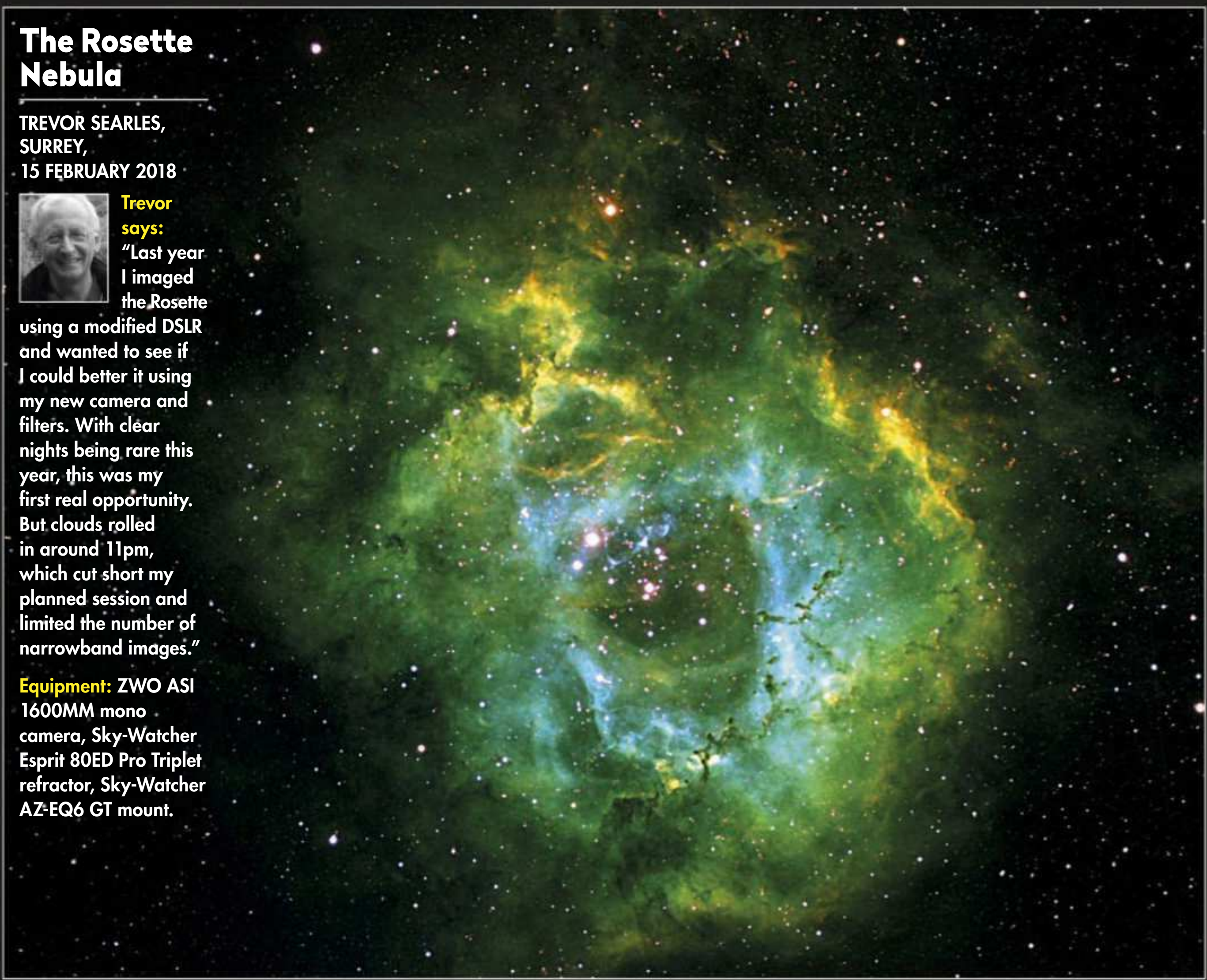
▼ The Andromeda Galaxy

JASON WISEMAN, TORBAY, 1 JANUARY 2018

Jason says: "The weather forecast was clear but not for long, so the target choice was for speed. We collected 35 minutes of light before the clouds rolled in. I am pleased with this result even though it did take quite a lot of processing to remove the noise from light pollution and reveal the finer details within Andromeda's structures."

Equipment: Canon EOS 550D DSLR camera, Celestron EdgeHD 14 Schmidt-Cassegrain, Sky-Watcher EQ8 Pro equatorial mount.





The Rosette Nebula

TREVOR SEARLES, SURREY, 15 FEBRUARY 2018

Trevor says: "Last year I imaged the Rosette using a modified DSLR and wanted to see if I could better it using my new camera and filters. With clear nights being rare this year, this was my first real opportunity. But clouds rolled in around 11pm, which cut short my planned session and limited the number of narrowband images."

Equipment: ZWO ASI 1600MM mono camera, Sky-Watcher Esprit 80ED Pro Triplet refractor, Sky-Watcher AZ-EQ6 GT mount.

◀ Slaley skyscape

GARY PESCOD, SLALEY FOREST, NORTHUMBERLAND NATIONAL PARK, 13 FEBRUARY 2018

Gary says: "I visited the Dark Sky Park in Northumberland after a spell of snow. The sub-zero temperatures seemed a bit of a challenge but the sky was clear so I persevered. I set up on the roadside, waiting almost an hour for a vehicle to pass to add the trails."

Equipment: Pentax K-5 II DSLR camera, Samyang 10mm lens.

▲ The Orion Nebula

DAVID LIAROMATIS, OXFORDSHIRE, 9, 12, 13 FEBRUARY 2018

David says: "I last imaged the Nebula in 2012 with a one-shot, colour camera. Now I'm mono imaging. I tested my processing skills with an LHaRHaGB combo in *PixInsight* with 5.5 hours of data."

Equipment: ZWO ASI 1600MM mono camera, Teleskop Service 65mm quadruplet astrograph, Sky-Watcher NEQ6 Pro SynScan mount.

The Pinwheel Galaxy ▶

MARIO RICHTER, BRANDENBURG, GERMANY, 16 FEBRUARY 2018

Mario says: "Since I wanted to photograph a galaxy and needed a long focal length with a fast aperture ratio, I set up my Newtonian instead of the Takahashi refractor. The night was very humid and at –13°C the equipment was frozen very fast, so I only had enough time for 27 lights at 480 seconds."

Equipment: Canon EOS 60D DSLR camera, Celestron Advanced VX 8-inch Newtonian, Sky-Watcher EQ6-R Pro SynScan mount.

Sh2-174 ▶

JENS ZIPPEL, BREMEN, GERMANY, 20 FEBRUARY 2018

Jens says: "This project was developed in cooperation with Marcel Drechsler, who provided additional data from his observatory at Bärenstein. We decided to capture this object because it was a real challenge. There are only a few images of it taken by amateurs, because it is so faint."

Equipment: Atik 460EX mono, Atik 490EX mono, ZWO ASI 1600MM mono cameras, 10-inch f/4 Newtonian, Celestron 11-inch Rowe-Ackermann Schmidt astrograph, Takahashi Epsilon 130D Newtonian, Sky-Watcher EQ8 Pro mount, Lodestar off-axis guider.

▼ The Lagoon & Trifid Nebulae

PETER LOUER, TENERIFE, 27 FEBRUARY 2018

Peter says: "I'm very lucky to live in the north of Tenerife and although I have a street light outside my house, with the incredibly clear skies and an IDAS light pollution filter I can manage shots like this without too many problems."

Equipment: Canon EOS 600D DSLR camera, Canon 100-400mm lens, Sky-Watcher Star Adventurer mount.

ENTER TO WIN A PRIZE!

ALTAIR ✶ ASTRO We've teamed up with Altair Astro UK to offer the winner of next month's Hotshots an Altair Astro Premium 1.25-inch CLS-CCD Filter with UV/IR Block & AR Coating, designed to reduce the effects of light pollution and skyglow for DSLR, CCD or CMOS cameras – www.altairastro.com • 01263 731505

Submit your pictures via www.skyatnightmagazine.com/astrophotography/gallery or email hotshots@skyatnightmagazine.com. T&Cs: www.immediate.co.uk/terms-and-conditions

Remembering Stephen HAWKING

08.01.1942 – 14.03.2018

One of modern cosmology's most brilliant minds and sharpest wits passed away in March. **Paul Sutherland** looks back at the life of Stephen Hawking

◂ Physicist, wit, author, occasional Transformer and general genius, Stephen Hawking not only rewrote the science books, but also helped break down prejudices about disability

Stephen Hawking's death on 14 March, aged 76, robbed the world of one of its most recognisable scientists. His genius was compared to the likes of Isaac Newton and Albert Einstein, and though a cruel illness confined him to a motorised wheelchair for most of his life, his brilliant mind took him to the farthest reaches of the Universe.

Professor Hawking was born in Oxford on 8 January 1942, the 300th anniversary of Galileo's death. He was the eldest of four. Father Frank was an expert in tropical diseases and, like mother Isobel, a former student at Oxford. Hawking showed an early interest in astronomy and was encouraged by Isobel to look at the stars from their garden. The family moved to St Albans when Hawking was eight. He was rather laid back at school, but won a place at University College, Oxford, at 17, achieving a First Class Honours degree in Natural Science.

Hawking moved on to the Department of Applied Mathematics and Theoretical Physics at Cambridge in 1962 to pursue a PhD in cosmology. He had hoped to study under the legendary Fred Hoyle, but had to settle for a less well-known supervisor, Dennis Sciama. This was probably fortunate because, whereas Hoyle was rather fixated on the notion of a Universe that had always been around, Sciama enthusiastically supported new ideas in cosmology. A long-running debate over how the Universe began was favouring the concept of a Big Bang – a name coined by Hoyle in an interview as a term of derision – and there was growing interest in the existence of black holes.

Hawking was fascinated by the idea of black holes, known as singularities back then. He saw the Big Bang as being like a singularity in reverse. Whereas anything that fell into a black hole essentially disappeared, the whole of space and time had sprung spontaneously into existence.

Expanding the universe

By this time Hawking had noticed increasing problems with his health, including occasional falls and slurring of speech. In 1963, aged 21, he was diagnosed as suffering from amyotrophic lateral sclerosis, a form of motor neurone disease that removes muscular control.

Fortunately the disease did not diminish the mind. Hawking overcame initial depression and threw himself into his work. And though some had feared he would not live long enough to complete his PhD, he confounded them by surviving a further 55 years.

Hawking achieved his PhD in 1965 with his thesis Properties of Expanding Universes, examining how galaxies and black holes form and evolve. The University of Cambridge made it freely ▸

Hawking coxed at Oxford, but his daredevil steering led to the boat often being returned to the shed with damaged blades

JASON BYE/ALAMY STOCK PHOTO, KRZYSZTOF JAKUBCZYK/ALAMY STOCK PHOTO

► Hawking married Jane Wilde in St Albans in 1965. "We didn't know how long Stephen was going to live," Jane later recalled

► available to download in 2017. Demand was so great, it brought down the server.

Hawking published his first academic book, *The Large Scale Structure of Space-Time*, with colleague George Ellis in 1973. One of its major points was that the area of a black hole's event horizon, beyond which everything was forever lost, could never decrease in size. A year later, aged just 32, he was elected a Fellow of the Royal Society. And in 1979 he became Lucasian Professor of Mathematics at Cambridge, a post held by Newton.

Hawking was showing growing interest in the very small as well as the astronomically large, turning his attention to the science of atomic particles, or quantum theory, and how it related to the Universe. It led to his most famous discovery, that black holes leak energy back into space and will eventually evaporate.

The natural order of the Universe is to become more chaotic, a phenomenon called entropy. If matter falling into a black hole took its entropy with it, that would violate the second law of thermodynamics, which says that the total entropy in the Universe always increases.

A young American scientist, Jacob Bekenstein, suggested that the black hole's growing event horizon might hold on to the entropy that appeared lost. Hawking set out to prove the idea wrong, but instead, in 1974, showed mathematically how it happens. He realised that as one particle disappeared into a black hole, another must escape from its edge. This became known as Hawking radiation. The force would be so small as to be undetectable in black holes observed across the cosmos. But Hawking believed that the Big Bang itself produced tiny black holes, smaller than atoms, that each exploded with the force of a million hydrogen bombs.

"He believed the Big Bang created sub-atomic black holes that exploded with the force of a million hydrogen bombs"

Hawking also changed his opinion on another challenging problem, namely what happens to all the information that falls into a black hole once it evaporates away. In 1976 he argued that the information was forever lost, even though quantum mechanics did not allow for that. But in 2004 he admitted he was wrong.

Following mapping of background radiation from the Big Bang by the Cosmic Background Explorer satellite, COBE, in 1992, Hawking said it showed fluctuations from slight irregularities in the Universe that caused regions to collapse to form stars and galaxies. Other fields of interest included the possibility that black holes might be the seeds of other, baby universes. And in an idea straight out of *Doctor Who*, he suggested that wormholes in the space-time continuum could provide short cuts across the Universe.

A defining voice

All the while that Hawking was investigating the mysteries of the Universe, he was facing more personal challenges. After contracting pneumonia in 1987, he underwent a tracheotomy and lost his already limited ability to speak. A speech synthesiser gave him the robotic voice that would become synonymous with him. At first he could operate it with his hand, but eventually only with a twitch of his cheek, making it a slow and tedious process.

Cambridge students claimed Hawking could be a menace on campus with his wheelchair. He even joked himself about being a bad driver

ABOUT THE WRITER

Author and journalist Paul Sutherland is a member of the British Astronomical Association and the Association of British Science Writers

KRZYSZTOF JAKUBCZYK/ALAMY STOCK PHOTO X 2, LIAM WHITE/ALAMY STOCK PHOTO, PHOTO 12/ALAMY STOCK PHOTO, EVERETT COLLECTION INC/ALAMY STOCK PHOTO, WHITE HOUSE PHOTO/ALAMY STOCK PHOTO, ROPI/ALAMY STOCK PHOTO

HAWKING IN POPULAR CULTURE

The eminent cosmologist was adopted by the media at large, ensuring his name spread far and wide

Hawking became such an inspiration that a film, *The Theory of Everything*, was released in 2014 about his remarkable early life. It was based on a memoir by wife Jane, and Eddie Redmayne won an Academy Award for playing the physicist.

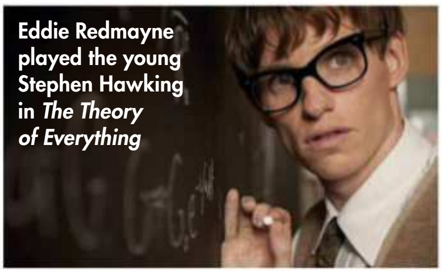
Proof that Hawking had captured the public imagination followed the publication of his book, *A Brief History of Time*, in 1988. Despite being a challenging read, it became an instant bestseller, which has since been translated into more than 40 languages and sold millions of copies. Hawking went on to write a total of 15 books, including some for children with his daughter Lucy. He also made numerous TV appearances, including in his own series, *Stephen Hawking's Universe*, for the Discovery Channel in 2010.

The physicist showed his sense of fun by appearing in lighter entertainment from *The Simpsons* and *Futurama* to *Red Dwarf* and *Star Trek: The Next Generation*, in which he was seen playing cards with Einstein and Newton. He featured in several episodes of comedy *The Big Bang Theory*, and performed a skit with *Little Britain*'s David Walliams in which he turned into a Transformer robot.

In another comedy sketch, shown on the *Monty Python Live (Mostly)* shows in 2014, Hawking sang a version of Eric Idle's *The Galaxy Song* after running down Professor Brian Cox in his wheelchair.

Hawking helped make a number of TV advertisements. His voice was used for a BT TV commercial that was sampled by Pink Floyd for tracks on their albums *The Division Bell* and *The Endless River*.

One of his final broadcasts was a cameo as The Guide Mark II in the *The Hitchhiker's Guide to the Galaxy: Hexagonal Phase*, which aired on Radio 4 earlier this year.



Eddie Redmayne played the young Stephen Hawking in *The Theory of Everything*

Hawking cameos on *Futurama*

Barack Obama chats with Hawking and his daughter Lucy before presenting him with his Presidential Medal of Freedom in August 2009

"I could have gone on and on. Space, here I come," said Hawking after his Zero-G flight in 2007

Despite advances in speech synthesis, he stuck with the original voice that became his trademark.

Hawking had married family friend Jane Wilde in 1965, and they had three children, Robert, Lucy and Timothy. The couple divorced in 1995 and Hawking married one of his nurses, Elaine Mason. That relationship ended in 2006 after which Hawking grew close to Jane again.

Hawking had a great sense of fun, and those who met him remarked on the twinkle in his eye. By all accounts he loved to party, and his lectures – many viewable online – are laced with jokes.

Hawking was awarded the Presidential Medal of Freedom by Barack Obama in 2009. He used his status to shine a light on wider issues than cosmology, urging humanity to move swiftly to colonise other worlds before catastrophe struck our own. And in 2014, he warned of the rise of the robots, saying artificial intelligence could spell the end of the human race.

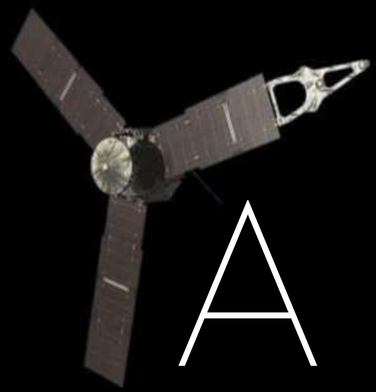
The professor also feared that alerting alien races to our presence could end badly for us. But in 2016 he was a leading supporter of Breakthrough Starshot's plan to send a fleet of tiny spacecraft to Alpha Centauri to search for habitable planets. On more down-to-earth issues, he championed the National Health Service.

Hawking had been a physically active youth, and a rowing coxswain at Oxford. Despite his illness he never lost his sense of adventure. He travelled the world and was offered a sub-orbital flight by Virgin Galactic after he told of his desire to go into space. While he never achieved spaceflight, he did experience weightlessness in 2007 on a parabolic flight with the Zero-G Corporation.

Perhaps Hawking's greatest proof was that physical disability need not hamper a full and successful life. His achievements will ensure his name lives on.

BBC iPlayer Radio

Listen to Stephen Hawking's 2016 Reith Lectures on black holes, originally broadcast on Radio 4: **https://bbc.in/23ka4V5**



A new JUPITER

Ben Evans looks at how the Juno mission has allowed us to rediscover the Solar System's largest planet, revealing its unusual features in greater detail than ever before

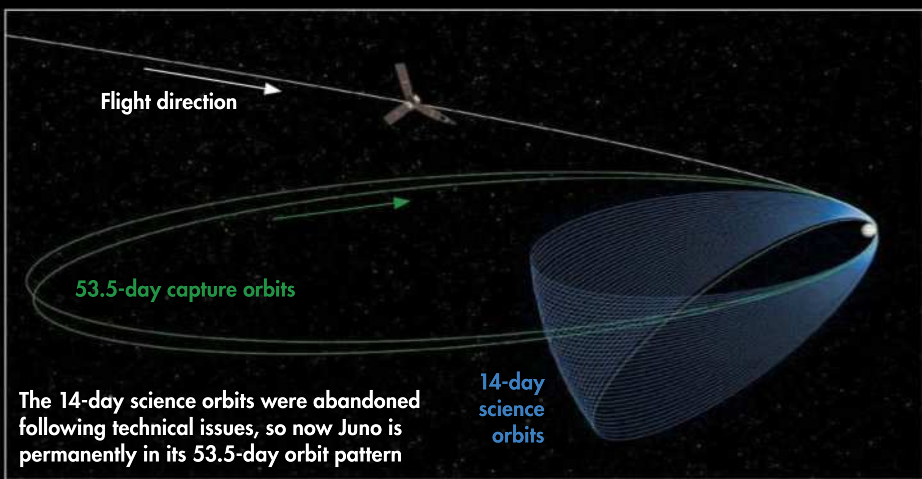
For two years, a torrent of images – the surreal intricacy of which evokes the work of Salvador Dali, while their almost impressionistic juxtaposition of light and shade would delight Claude Monet – has been journeying across 870 million km of space to fascinate an Earthly audience. Since reaching Jupiter in July 2016, Juno has become the first spacecraft to enter polar orbit around the Solar System's largest planet and the first to actively engage with the public to determine what it should be observing. In doing so, Juno has transformed Jupiter from a planet into an objet d'art.

Launched in August 2011, Juno's 2.8 billion km journey took it into Jupiter's gravitational clutches at a relative velocity of 265,500km/h, faster than any man-made object in history. Juno entered an elliptical 53.5-day capture orbit, passing 4,200km over the planet at its closest ('perijove') and sweeping outward to 8.1 million km at its farthest ('apojove'). The original plan was for Juno to complete two capture orbits, then enter a repeating 14-day science orbit for 37 pole-to-pole laps of Jupiter. But Juno was always intended to be a voyage into the unknown, and the unknown has a habit of throwing curveballs.

One such curveball hit the mission in October 2016 soon after Juno had settled into its capture orbit. A set of sluggish helium valves forced managers to delay firing the engines that would send it into its science orbit. Matters worsened when the spacecraft put itself into safe mode, following a computer reboot. In February 2017, fearful that firing the engines might impair the mission, NASA opted to keep Juno permanently in its 53.5-day orbit.

Circling Jupiter on this looping ellipse permits global mapping of its magnetosphere, which extends 8 million km towards the Sun and spirals beyond the planet in a tadpole-like magnetotail. The hydrogen-helium atmosphere is tightly compressed by gravity and virtually impenetrable. But by flying so close to Jupiter, Juno envelops it in a 'net' of observations, yielding insights into ▸

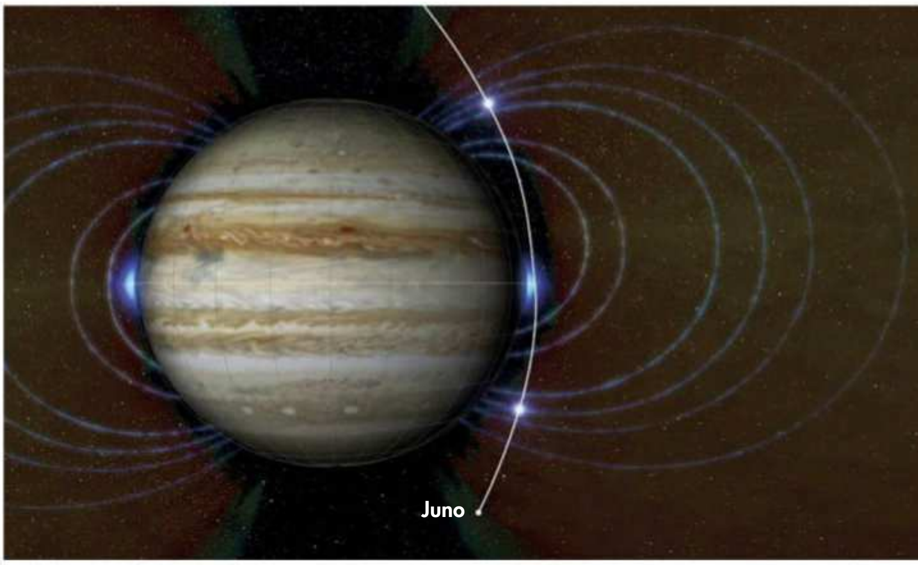
ABOUT THE WRITER
Ben Evans has written nine books on space exploration and is the senior writer for AmericaSpace.com



The 14-day science orbits were abandoned following technical issues, so now Juno is permanently in its 53.5-day orbit pattern

NASA/JPL-CALTECH/SWRI/MSSS/GERALD EICHSTADT/ SEAN DORAN, NASA/JPL-CALTECH X 2

Jupiter's striking and surprisingly blue South Pole, captured by JunoCam on 19 May 2017, taken about 46,900km above the cloud tops



▲ NASA's illustration of a new radiation zone discovered by Juno, shown here as a glowing blue area around the planet's middle

▸ its magnetic field, its core and an electrically-conducting inner 'shell' of metallic hydrogen.

In May 2017, Juno showed the magnetic field to be strangely 'lumpy' – stronger in some places, weaker in others – but still many times more powerful than the strongest fields on Earth. "This uneven distribution," says deputy principal investigator Jack Connerney, "suggests that the field might be generated by dynamo action closer to the surface, above the layer of metallic hydrogen."

Juno's close perijove orbit coincidentally also enabled the discovery of a new equatorial radiation belt, characterised by energetic hydrogen, oxygen and sulphur ions. "We only found it because Juno's unique orbit allows it to get really close to the cloud-tops," explains physicist Heidi Becker, "and we literally flew through it."

It is thought that the particles derive from energetic neutral atoms from the moons Io and Europa, which are stripped of their electrons by interaction with Jupiter's upper atmosphere.

No dive to destruction... yet

The capture orbit also benefits Juno's longevity. A 14-day science orbit would have exposed it to significant radiation and an elevated risk of hardware failure, as well as endangering the moons Europa, Ganymede and Callisto, which might possess subsurface oceans. Balancing this life-limiting radiation dosage against the need to safeguard potentially life-bearing moons, the mission was targeted to end in February 2018 with a destructive dive into Jupiter's atmosphere. However, the 53.5-day orbit carries Juno through more benign radiation, allowing it to endure until July 2018 and possibly longer.

"Every 53 days," says principal investigator Scott Bolton, "we go screaming by Jupiter, getting doused by a fire-hose of Jovian science and there is always something new."

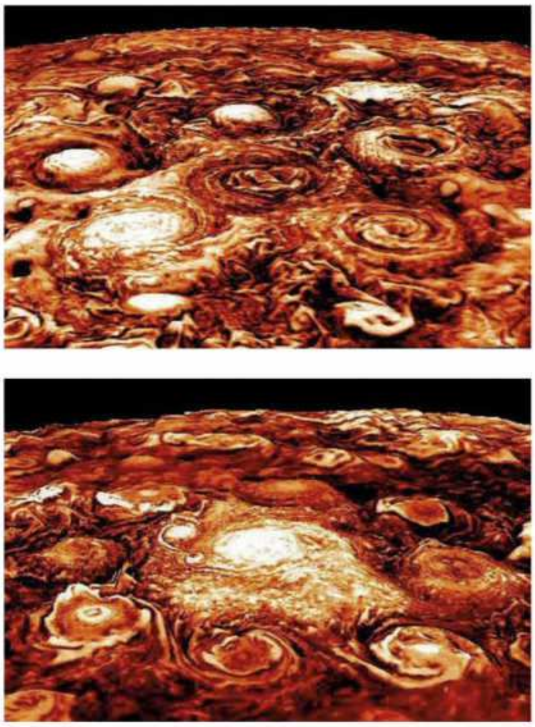
Key findings include polar aurorae that function quite differently to our Northern and Southern Lights. Ultraviolet and energetic-particle data showed that the signatures of powerful electric currents, aligned with the Jovian field, accelerate electrons at energies up to 400,000 electron-volts, some 10-30 times higher than Earth's aurorae. As the power density strengthens, the process destabilises and other mechanisms take over. Radio emissions, shifted into the audio range, have even allowed the public to hear Jupiter's ghostly 'voice'.

And on this mission, the public has a ringside seat. Thanks to JunoCam, its visible-light camera, atmospheric features can be imaged in colour, at resolutions as fine as 2.9km per pixel, by 'citizen scientists'. In January 2017, NASA initiated an online voting campaign to pick regions for Juno to photograph during successive perijoves, as it completed each two-hour, north-to-south sweep.

Before Juno, Jupiter's poles had never been seen. "It's bluer up there and there are a lot of storms," explains Bolton. "There is no sign of the latitudinal bands or zones and belts that we are used to."

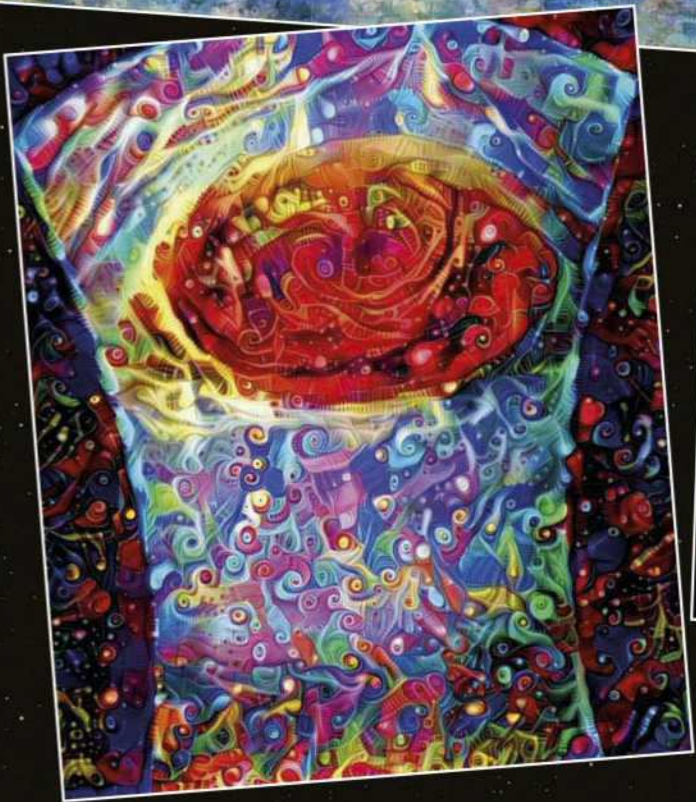
Both of the poles feature a huge central vortex surrounded by swirling groups of cyclones – eight in the north, five in the south – with winds peaking at 350km/h. The northern cyclones measure up to 4,600km across, whilst their southern cousins are even larger, reaching almost 7,000km in diameter.

These cyclones are enduring features, having been observed continuously by Juno for many months. Despite being densely packed together, ▸



◂ Two computer-generated images of Jupiter's south (top) and north (bottom) polar regions, based on data captured by Juno's Jovian Infrared Auroral Mapper (JIRAM) instrument. Note how both have a central cyclone surrounded by a number of smaller ones

◄ David Englund's avant-garde work reinterprets the Great Red Spot in the style of Claude Monet



◄ Eco artist Mik Petter gives the Jovian landscape a colourful fractal makeover

▲ It's not just Mars that has people seeing ghostly faces. Meet Jovey McJupiterFace

JUNOCAM

a camera for the public

JunoCam has made it possible for amateur astronomers to take their own photos of Jupiter

Of all Juno's eight science instruments, the one that has undoubtedly captured the public's imagination like no other is JunoCam.

This visible-light camera, with a 58° field of view, was intended to facilitate unprecedented educational outreach and NASA has invited 'citizen scientists' to select regions to photograph during each perijove passage. Telescope observations by ground-based astronomers and an ability to plot atmospheric features directly onto the mission's website have enabled Jupiter to be imaged by members of the public at resolutions as fine as 2.9km per pixel.

Described as "the public's camera" and "science in a fishbowl", JunoCam has produced stunningly surreal imagery of the Solar System's largest planet. Colour-enhanced views have presented Jupiter in vivid blues, reds, creams and browns and tracked swirling, contorting storms, spots and eddies, whilst artists and graphic designers have also been inspired to apply their craft to the bewildering perspectives.

Mik Petter used mathematical formulae to digitally re-imagine the Great Red Spot as something akin to a petri dish, overcrowded with colourised microorganisms, whilst David Englund created a composition of which French impressionist Monet would have been proud. Others have introduced an element of fun. One view, captured in May 2017, was dubbed 'Jovey McJupiterFace' by citizen scientist Jason Major, on account of its spooky similarity to a human face, complete with two raging storms in place of eyeballs.

Durable Juno

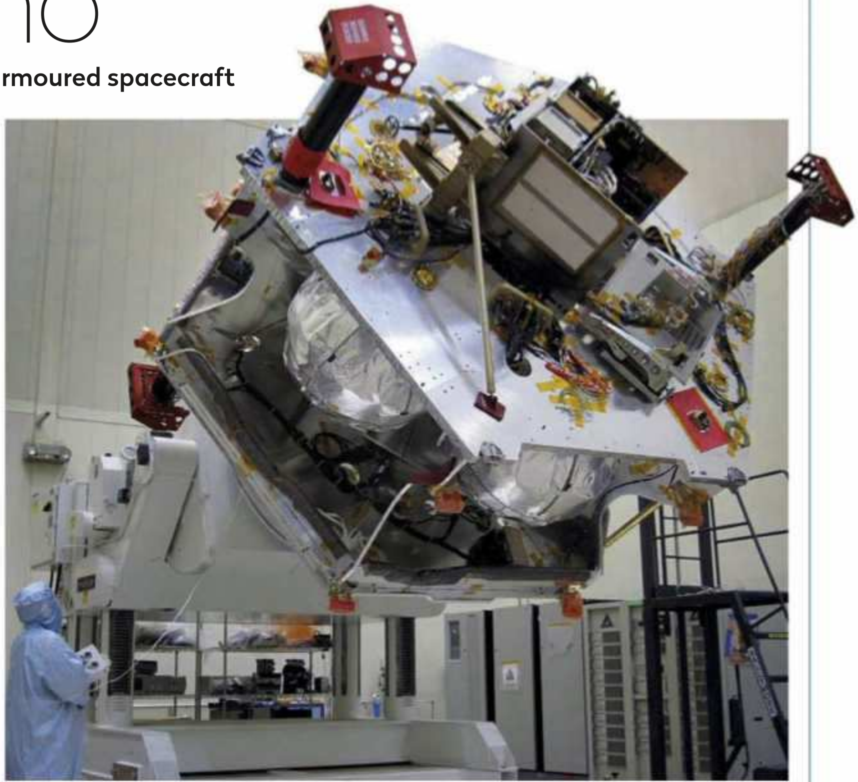
Jupiter's intense radiation called for a robust, armoured spacecraft

Approaching Jupiter more closely than any other spacecraft and surviving the fiercest planetary magnetic and radiation environment in the Solar System was always going to be a formidable challenge. Most of Juno's electronics, including its RAD750 microprocessor, are composed of radiation-resistant tantalum, with wiring sheathed in a copper and stainless steel braid, all encased within the 10mm-thick walls of a cube-shaped titanium vault. Although not impenetrable, the vault reduces radiation damage by 800 times.

For extra robustness, Juno's hardware was built bigger and external components – solar panels, cameras, sensors – received added protection, including 12mm-thick glass sheets. Ground-based electron tests showed the solar panels would lose 0-15 per cent of their output at Jupiter, so were built 10-15 per cent bigger. Over its lifetime, the spacecraft will endure the equivalent of 100 million dental X-rays.

"Juno is basically an armoured tank," says principal investigator Scott Bolton. "Without its protective shield or radiation vault, Juno's brain would get fried on the very first pass."

Much of its 53.5-day orbit is spent beyond the worst radiation, but at perijove it dives quickly through the searing equatorial regions. "We thread a needle," says Bolton. "By going over the poles, we're able to drop down in a small gap between the atmosphere and these intense radiation belts."



▲ Just after having had its radiation vault fitted over its propulsion module, Juno is lifted on a rotation fixture at Lockheed Martin Space Systems, Denver in June 2010

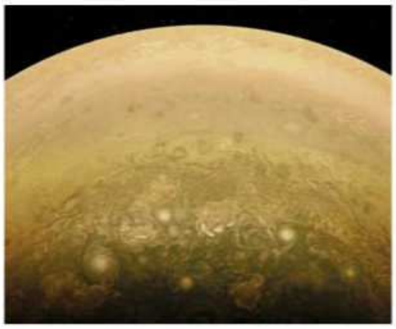
▸ and with their spiral arms frequently touching, they retain distinct, individual morphologies. At high northern latitudes, Juno also measured the Little Red Spot – the planet's third-biggest anticyclone – at half the size of Earth, whilst at 40° south it revealed the 'string of pearls', a chain of oval-shaped, counterclockwise-revolving storms.

Juno has sampled thermal microwave radiation from the atmosphere, revealing the equatorial belts penetrate deep inside the planet. So too do atmospheric winds, which endure far longer than similar processes on Earth. Contrastingly, higher-latitude belts and zones evolve into other structures, indicating variable ammonia concentrations. Water, although identified by earlier missions, remains surprisingly elusive. In October 2017, clouds of ammonia ice and possibly water were found. By measuring the oxygen-hydrogen ratio and water balance, theories on how Jupiter formed can be confidently addressed.

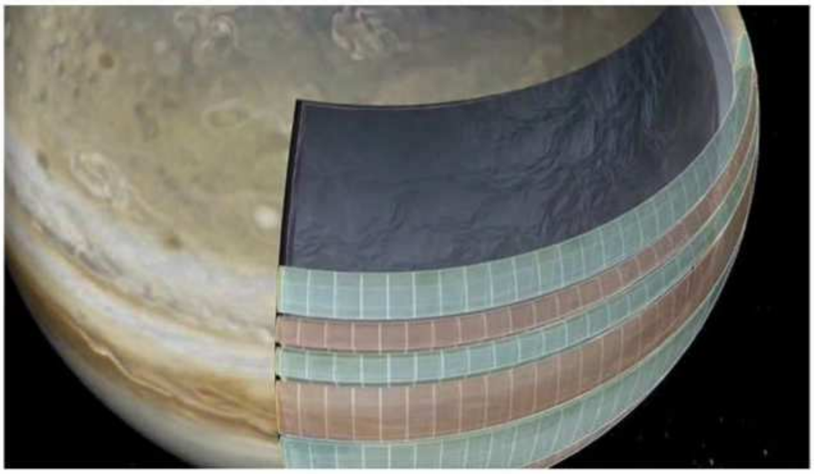
Gravity's regional variations

Gravitational observations, published in March 2018, indicate striking north-south asymmetries, not dissimilar to that seen in the belts and zones. This arises from gaseous flows deep within the planet and Juno showed that the visible eastward and westward jet streams also exhibit north-south asymmetry. The magnitude of this asymmetry allows the jets' depth to be determined. Remarkably,

▲ The Little Red Spot, a storm on the edge of Jupiter's northern polar region



▲ A JunoCam view of Jupiter's String of Pearls: actually vast, swirling storms



▲ Juno revealed that beneath Jupiter's writhing bands, its gas core acts like a rigid body

NASA/JPL-CALTECH/LMSS, NASA/JPL-CALTECH/SWRI/MSSS/GERALD EICHSTAEDT/JOHN ROGERS, NASA/JPL-CALTECH/SWRI/MSSS/ALEX MAI, NASA/YOUTUBE, NASA/JPL-CALTECH/SWRI/MSSS, NASA/JPL-CALTECH/SWRI/MSSS/KEVIN GILL

Scientists believe that the brighter clouds in this image are updrafts of ammonia ice crystals possibly mixed with water ice

"Microwave radiometry revealed that the Great Red Spot's roots plunge up to 100 times deeper than our oceans"

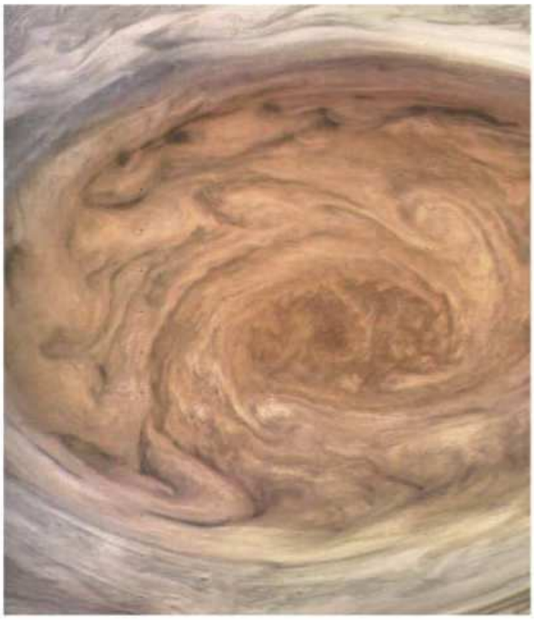
Jupiter's 3,000km-deep weather layer comprises one per cent of the planet's entire mass, compared to 0.000001 per cent in the case of Earth. And in one of the greatest surprises of the mission, this gaseous world rotates almost as a rigid body beneath its massive weather layer.

In July 2017, the spacecraft hurtled 9,000km over the famous Great Red Spot. This centuries-old storm has morphed in shape and diminished in size over time, today measuring 16,350km across – 1.3 times larger than Earth – and Juno detected a tangle of dark, veiny clouds weaving through it. Microwave radiometry revealed that its roots plunge to a depth of 300km, which is some 50-100 times deeper than our oceans.

For now, the future for this mission remains uncertain beyond July 2018, as Juno awaits its fate. Yet in two years it has revolutionised humanity's understanding of a world 1,300 times bigger than our own. "We knew that Jupiter would throw us some curves," says Bolton. "We didn't expect that we would have to take a step back and begin to rethink this as a whole new Jupiter." Ⓢ

BBC iPlayer

UK viewers can watch a 1995 episode of *The Sky at Night* in which Patrick Moore gets an update on the Galileo mission to Jupiter: **http://bbc.in/2oRoJK0**



▲ An enhanced-colour image of Jupiter's Great Red Spot which was created by citizen scientist Kevin Gill

An InSight inside MARS

InSight will arrive on Mars packed with all the equipment it needs to reveal the secrets at the core of the rocky planet

NASA/JPL-CALTECH

NASA plans to launch its next mission to Mars this month. Elizabeth Pearson looks at what InSight hopes to uncover deep beneath the Martian surface

ABOUT THE WRITER
Dr Elizabeth Pearson is the news editor at *BBC Sky at Night Magazine* and she holds a PhD in extragalactic astronomy

Dozens of robotic explorers have been sent to Mars over the decades, but so far most of them have done little more than scratch at the surface. NASA's next mission to the Red Planet, however, will look much deeper into the planet than any of its predecessors. The InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) lander is preparing to hunker down on the Martian surface, ready to take the planet's pulse and temperature, and peel back its layers to expose its very core.

The mission is due to launch in early May from Vandenberg Air Force Base, California, arriving at Mars six months later, to send a static lander to the surface on 26 November. However, as this is in the middle of the Martian autumn, when dust ▸

InSight will use thrusters to complete a descent flight plan identical to that of the Phoenix mission before it

> "RISE is tracking the wobble of Mars as it spins on its axis since planets with liquid cores wobble more" Suzanne Smrekar, NASA

▸ storms can sweep across the entire planet, the descent could be a fraught one. Luckily, this isn't the first time NASA has put down a probe like InSight.

"We tried to stick to the design of a previous lander, Phoenix, as much as possible," says Suzanne Smrekar, Deputy Principal Investigator of InSight. "First, we have an aeroshell that will slow us down when we hit the atmosphere. Then we have a parachute to take us most of the way through the atmosphere. Finally, for the last little bit we come down on rockets."

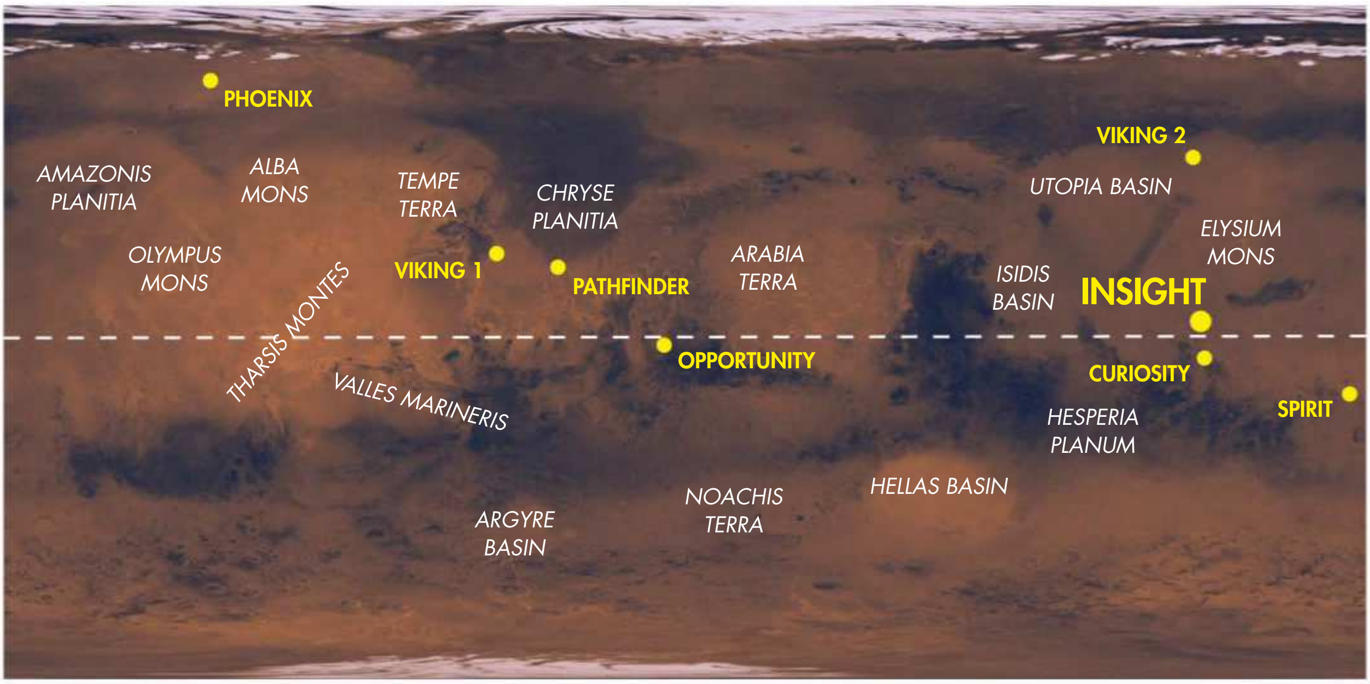
Once it has safely endured this landing and is on the surface, InSight will spend the next 10 weeks setting itself up. Its first task will be unfolding its solar arrays so that it can supply power to the lander. Then the mission will look around for the best place to put its fingers to the ground, so that it can feel for marsquakes – tremors created by the shifting of internal rocks, which radiate out from deep within the planet.

"Our primary instrument is a seismometer, the Seismic Experiment for Interior Structure (SEIS)," says Smrekar. "It actually has several short and long period seismometers to measure nearby seismic waves and those that come from deeper within the planet respectively. We have three of each so we can tell the direction and orientation that they are coming from."

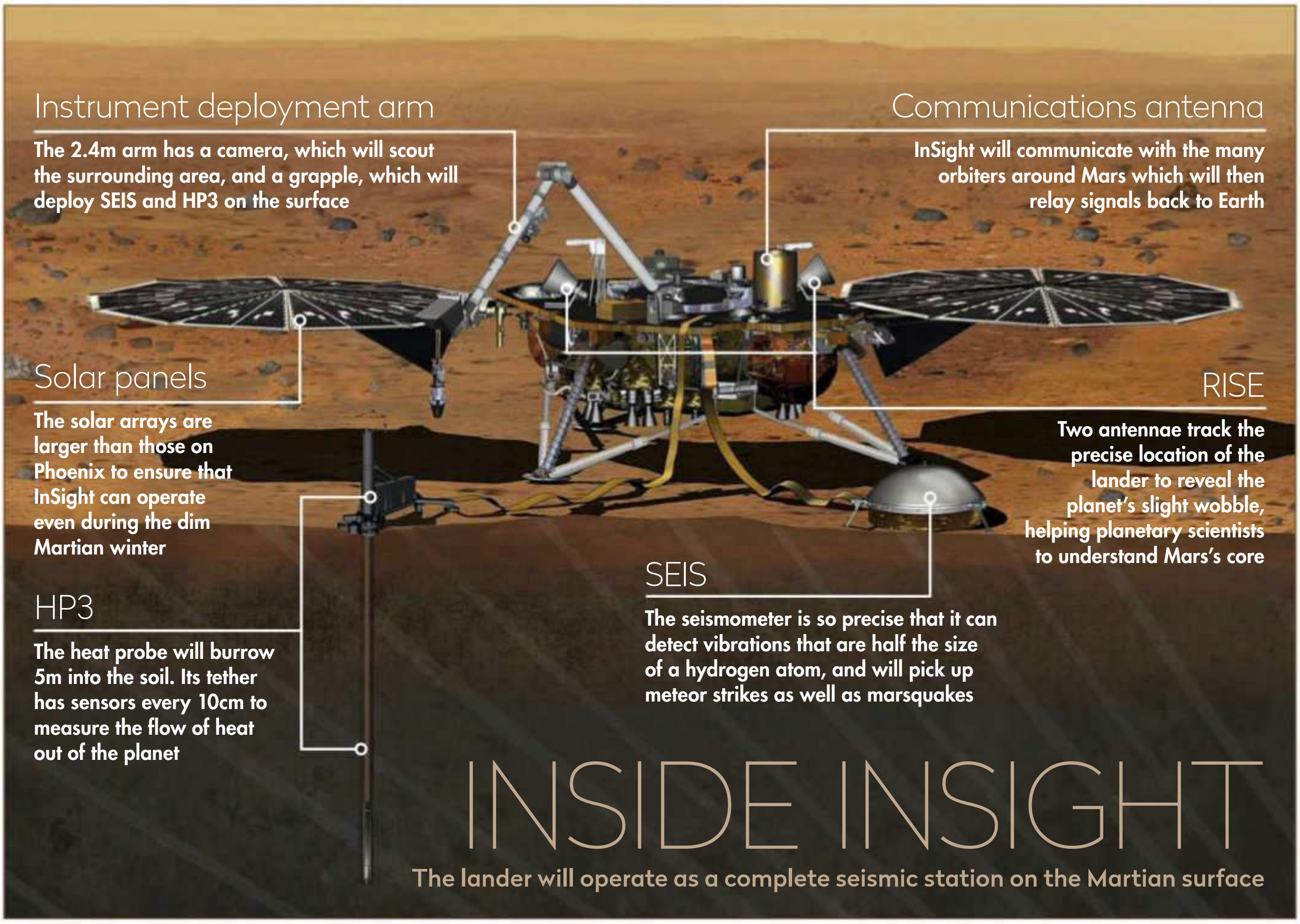
Measuring marsquakes

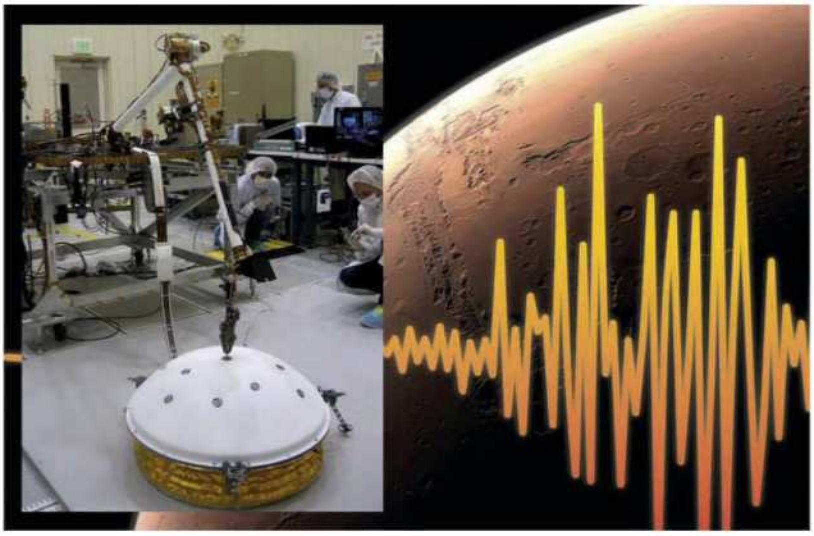
These seismometers are so sensitive that they have to be covered over with a dome that will protect them from tiny shakes caused by wind or thermal expansion to make them as precise as possible. Such

▼ The landing sites of all the successful Mars missions so far, plus the proposed equatorial landing site for InSight



NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA, NASA/JPL-CALTECH X 3, LOCKHEED MARTIN SPACE





▲ **InSight will measure seismic activity both near the surface and deep inside the core of Mars using the Seismic Experiment for Interior Structure (SEIS)**

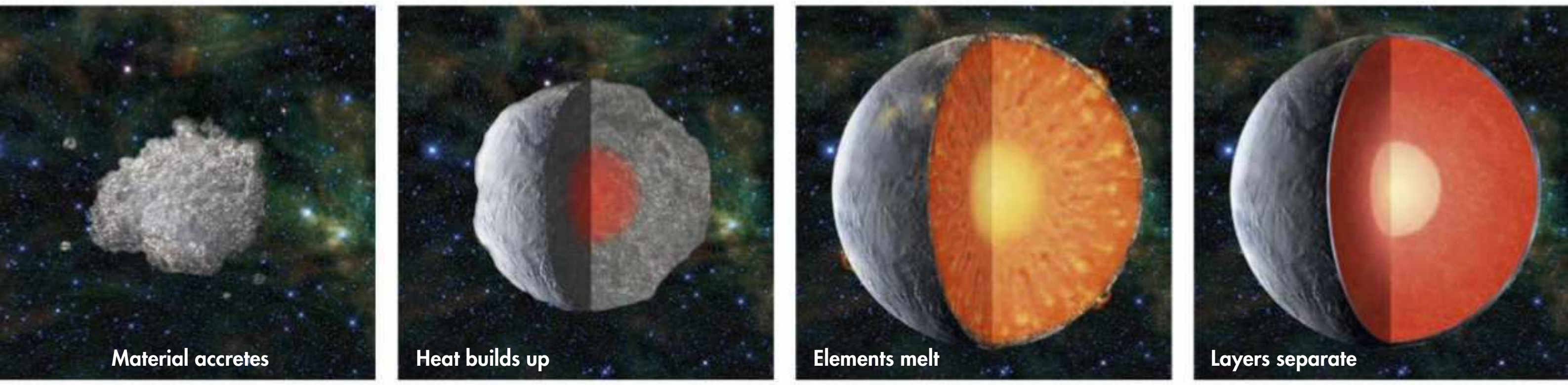
accuracy is vital in marsquake measurements to detect the tiny changes that occur when a seismic wave travels between the different layers inside the planet – going from the viscous fluid of the mantle to the solid crust, for instance. By looking for these tiny variations, planetary geologists will be able to work out the thickness and density of each layer, building a map of the world beneath the Martian surface. Gathering this knowledge is the first step to understanding how Mars grew and evolved into the planet we see today.

"We're trying to understand what happens immediately after the planets came together. The heat of that kinetic energy caused the bodies to melt and then relatively rapidly, within 10 million years, they began to form their initial layers as light stuff floated to the top and heavy stuff sank to the bottom forming the core, mantle and crust: a process called differentiation," says Smrekar.

Stunted growth

The extent to which a planet differentiates is mostly defined by how much heat it has and how hot a planet is mostly depends on its size. Small rocky bodies, like the Moon, rapidly cool after they form and so never fully differentiate their interior. Meanwhile Earth has kept evolving for billions of years because it's been kept warm by the decay of radioactive elements. As its interior is molten, the material there can redistribute itself inside the planet. The liquid layers also allow the continental plates to move around, changing the topography of the surface, while liquid magma bubbles up from volcanoes and covers what was there before. The end result is that Earth today bears little resemblance to the planet it was when it first formed billions of years ago. The same processes are thought to play out on the other, larger terrestrial worlds, but Mars has some unique geological qualities.

"Mars is in this sweet spot: we think it's in the right place in terms of its size that it never had plate tectonics, so it still has its initial crust, but it's big ▸



▲ A NASA artist's impression of how a rocky planet, such as Mars, is formed through processes known as accretion and differentiation

▸ enough that it has some of the same kinds of layers that we expect inside of the Earth," says Smrekar.

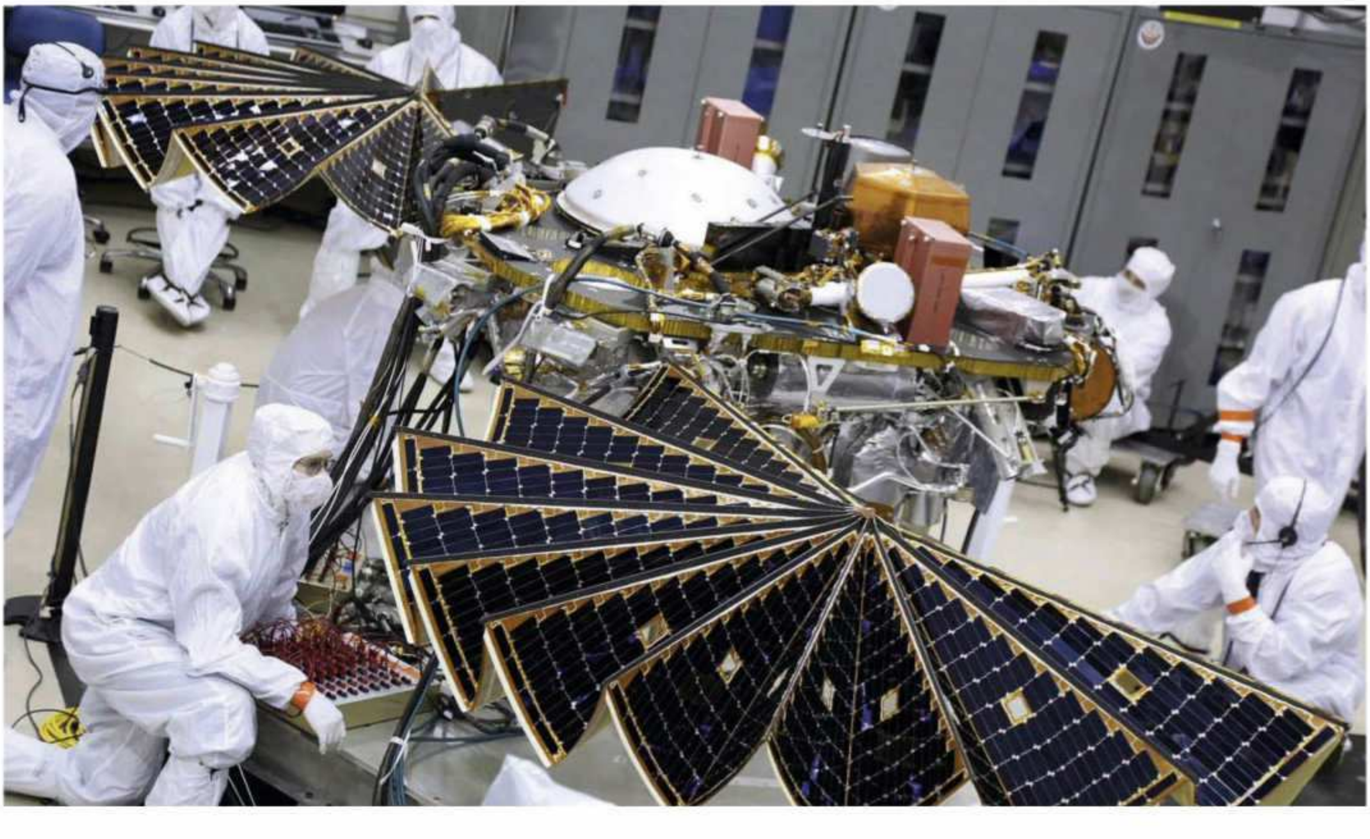
Although Mars started out developing like a larger rocky planet, it cooled and froze very early in its lifetime, halting its growth. As the planet hasn't changed in billions of years, it now gives geologists a window into the early years of planetary formation. And the key to understanding why Mars cooled while worlds like Earth didn't is finding out how the Red Planet lost its heat. To do this, InSight will deploy its second instrument, the Heat Flow and Physical Properties Probe (HP3).

"Most of the planet's current heat budget comes from the decay of radioactive elements: uranium, thorium, potassium. HP3 will help us extrapolate how much of those elements Mars had in the past, and how much energy there was to drive things like volcanoes on the surface of Mars, and what the surface temperature might have been," says Smrekar.

Running on the spot

To take these measurements, HP3 will use a heavy probe to hammer itself up to 5m into the ground, pulling a string of temperature sensors behind it that will measure the heat flowing out of the planet. Once everything is in place, the lander will cease all further movement so as not to disturb the two experiments. Fortunately, the fact that the lander

▼ InSight unfolds its solar arrays for a final test on 23 January 2018 in the Lockheed Martin clean room in Colorado



RISING FROM THE PHOENIX

InSight owes a big debt of gratitude to a previous lander that NASA put down on the Martian surface

InSight is using some of Phoenix's hand-me-downs

To those who follow Martian missions, InSight might look rather familiar. That's no surprise: it is closely based on the Phoenix lander, which touched down in Mars's polar region on 25 May 2008. The InSight team has borrowed the design for the lander's descent hardware, base structure and robotic arm from Phoenix, but added a completely new set of science instruments.

This helped to reduce costs dramatically but also put several limits on the mission. Phoenix only operated for six months, but InSight is designed to last for at least a Martian year, if not longer. This means it has to land on the equator, or the solar panels won't be able to collect enough power during the dim winter months. In addition, the descent systems will only work over a certain range of altitudes and the only place on the equator at the right elevation is the flat Elysium Planitia region.

The Phoenix mission itself was concerned with the surface, rather than what lay beneath, and attempted to find out how hospitable the Martian soil was to life, past or present. The robotic arm took soil samples that were then heated, revealing they contained water ice, and the chances of habitability initially looked bright.

The excitement was short-lived as Phoenix also found perchlorates, a chemical that reduces the freezing point of water. While this could mean it is possible for liquid water to exist on the surface, when combined with other minerals and subjected to Martian levels of ultraviolet radiation, perchlorates cause a 10-fold increase in cell death. If any life did evolve on Mars, it would have found itself in a very hostile environment.

▲ An image of water frost on Mars captured by the Phoenix Lander on 14 August 2008

▲ The Phoenix Mars Lander's robot arm scoops a sample for its Optical Microscope

▲ A trench dug out by Phoenix's robot arm which scientists believe reveals buried ice

▲ Above left: HP3 was originally designed to be part of the ExoMars mission until a redefinition of its aims resulted in the cancellation of all its geophysical experiments

Above right: The tip of the InSight drill, which the project's team has dubbed 'the mole'

is static doesn't matter – no matter where it comes to rest, it can measure heat flow and keep track of seismic signals. The immobility also benefits InSight's third and final main experiment: RISE.

"The Rotation and Interior Structure Experiment (RISE) are radios that will communicate with Earth every couple of days over Mars's year, tracking the placement of the lander very precisely," says Smrekar. "What we're really doing with them is tracking the wobble of Mars as it spins on its axis, since planets with liquid cores wobble more than planets with solid cores."

By measuring the wobble, planetary geologists will be able to determine more accurately the density and consistency of each layer, which will help them work out what elements might make up the planet's core. By tracking back, the InSight researchers will be able to piece together the geological processes that went into creating the rocky world that Mars is today, and so how planets such as Earth might have looked before they were transformed by billions of years of volcanism and geological development.

InSight is expected to have finished its initial science goals within one Martian year (which at 687 days is just shy of two Earth years) but the team has built the lander to last, and hopefully InSight will continue gathering data long after its initial run. It might even be able to detect the arrival of two fellow Mars explorers when they land: both NASA and ESA plan on sending rovers to the Red Planet in 2020, doubling the number of mobile observatories ranging across the planet's surface. But for the next two years, InSight will take advantage of the quiet, and sit waiting for Mars to shake out its hidden secrets.

The Sky Guide May

Jupiter reaches opposition this month giving rise to a whole host of intriguing Galilean moon and shadow transit events

PETE LAWRENCE

ABOUT THE WRITERS

Pete Lawrence is an astronomer and astro imager, and presents *The Sky at Night* monthly on BBC Four

Stephen Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 60

RED LIGHT FRIENDLY

To preserve your night vision, The Sky Guide can be read using a red light under dark skies

DON'T MISS...

✦ Peak of the Eta Aquariid meteor shower
✦ Saturn close to globular cluster M22
✦ Venus and the crescent Moon in the evening twilight

MAY **HIGHLIGHTS**

Your guide to the night sky this month

WEDNESDAY 2

The Galilean moon Io is in transit across Jupiter's disc as darkness falls, being centrally placed at around 21:45 BST (20:45 UT). Interestingly, Io appears to be chasing its shadow across the disc. This dark dot can be seen just ahead of the Moon.

WEDNESDAY 9

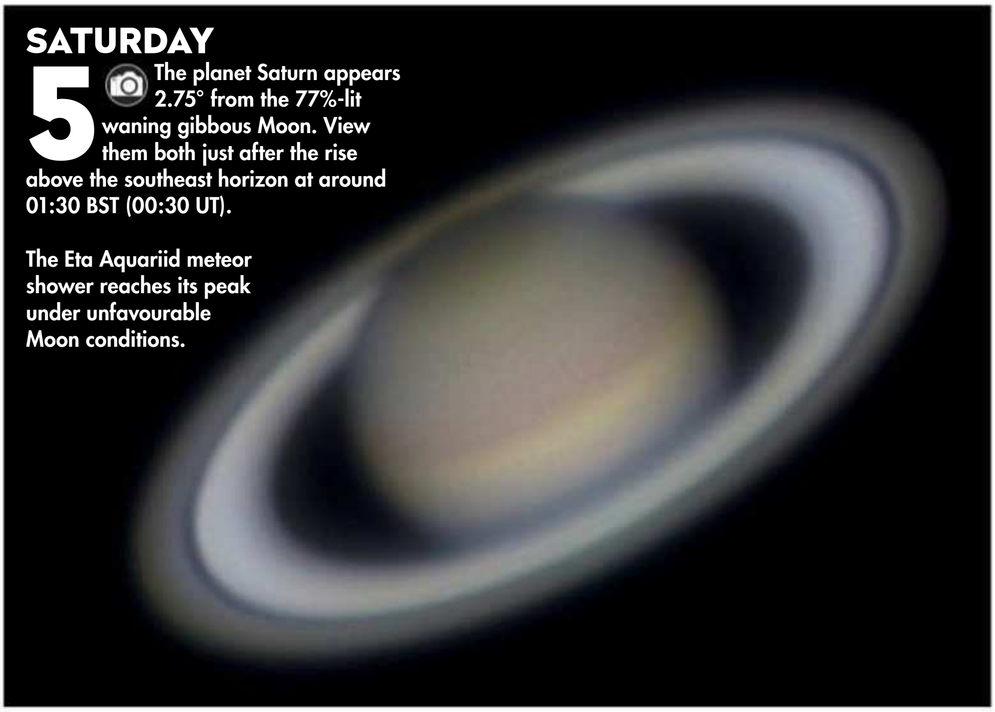
Jupiter reaches opposition today, appearing at its biggest and brightest for the year.

Yet another opportunity to catch Io in transit from 22:25 BST (21:25 UT) and again the moon appears virtually on top of its own shadow.

SATURDAY 5

The planet Saturn appears 2.75° from the 77%-lit waning gibbous Moon. View them both just after the rise above the southeast horizon at around 01:30 BST (00:30 UT).

The Eta Aquariid meteor shower reaches its peak under unfavourable Moon conditions.



◀ FRIDAY 11

The early morning Moon permits early season late-night viewing and photography of some of the showstoppers of the late spring and summer sky. Objects such as M57, the Ring Nebula, in Lyra; and M13, the Great Globular in Hercules (pictured).

SATURDAY 12

This is a good morning to try for this month's Moonwatch target, the 88km-diameter crater Byrgius (see page 58). The evening terminator will be approaching Byrgius this morning, with the crater lying on the terminator on the morning of 13 May.

TUESDAY 15

Saturn appears just 1.5° above the mag. +6.5 globular cluster M22 in Sagittarius at the moment. View both objects with binoculars or a small telescope from 02:00 BST (01:00 UT) low above the southeast horizon.

WEDNESDAY 16

The Moon is currently out of the way making this an excellent night to follow our Deep Sky Tour on page 62.

Io is in transit from 00:06 BST on 17 May (23:06 UT on 16 May) followed immediately by its shadow.

MONDAY ▶ 21

The end of May marks the start of noctilucent cloud (NLC) spotting season. This year, the Moon will be full at the end of May which may interfere with the visibility of any early NLC displays.

PETE LAWRENCE X 7

WEDNESDAY 23

Jupiter's disc will pass in front of the mag. +12.3 star TYC 6168-686-1 at 02:00 BST (01:00 UT) this morning. The brightness difference between Jupiter and the star will make this a challenging event to see and photograph.

SUNDAY ▶ 6

Mars and a 58%-lit waning gibbous Moon appear close this morning, reaching a separation under 2° in the daytime sky at 08:00 BST (07:00 UT).

Catch giant moon Ganymede in transit across Jupiter's disc. View from 22:00 BST (21:00 UT).

TUESDAY 8

Another chance to catch Io in transit across Jupiter's disc. View from 04:00 BST (03:00 UT). With opposition occurring tomorrow, Io is now virtually on top of its own shadow.

◀ THURSDAY 10

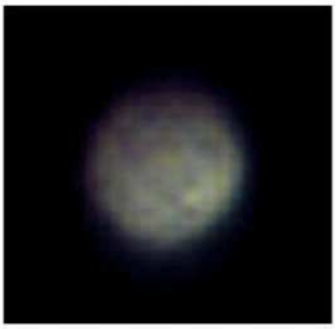
Comet 21P/ Giacobini-Zinner will be passing close to the Dumbbell Nebula, M27, this and tomorrow evening. See page 53 for more details.

SUNDAY 13

Now past opposition, as the Galilean moon Europa transits across Jupiter's disc from 01:30 BST (00:30 UT) its shadow follows it across the planet's atmosphere.

MONDAY ▶ 14

If you found yesterday's transit and shadow transit of Europa difficult to see, this morning from 01:30 BST (00:30 UT) the task is made much easier as giant moon Ganymede transits Jupiter's disc and is also preceded by its shadow. Callisto is also just north of Jupiter.



THURSDAY 17

The monthly meeting between brilliant planet Venus and the evening crescent Moon continues with the planet appearing 5.5° north of the 7%-lit waxing crescent Moon. Look for this lovely pairing 30 minutes after sunset, low in the west-northwest.

◀ SUNDAY 20

Although the bright evening twilight will make it hard to see, Venus appears a little under 1° from the beautiful open cluster M35 in Gemini this and tomorrow evening.

SUNDAY 27

Just past full, the Moon will be just 3.3° apart from Jupiter in the evening sky around 22:00 BST (21:00 UT).

FAMILY STARGAZING – ALL MONTH

Jupiter can be located early evening, visible as the brightest object low down, east of south. A small telescope reveals its four largest moons, which really capture the imagination of younger observers. View over several nights and note how they change position. Using our guide on page 56, see if you can identify which is which. On pages 50-52 we describe some interesting moon shadow events, which add further interest. The mnemonic "I Eat Green Cabbage" is a way to learn the order of the four 'Galilean' moons out from Jupiter, the initial letters representing Io, Europa, Ganymede and Callisto.

NEED TO KNOW

The terms and symbols used in *The Sky Guide*

UNIVERSAL TIME (UT) AND BRITISH SUMMER TIME (BST)

Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

RA (RIGHT ASCENSION) AND DEC. (DECLINATION)

These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'.

FAMILY FRIENDLY Objects marked with this icon are perfect for showing to children

NAKED EYE Allow 20 minutes for your eyes to become dark-adapted

PHOTO OPPORTUNITY Use a CCD, planetary camera or standard DSLR

BINOCULARS 10x50 recommended

SMALL/ MEDIUM SCOPE Reflector/SCT under 6 inches, refractor under 4 inches

LARGE SCOPE Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing a scope.

THE BIG **THREE**

The three top sights to observe or image this month

DON'T **MISS**

Jupiter moon events

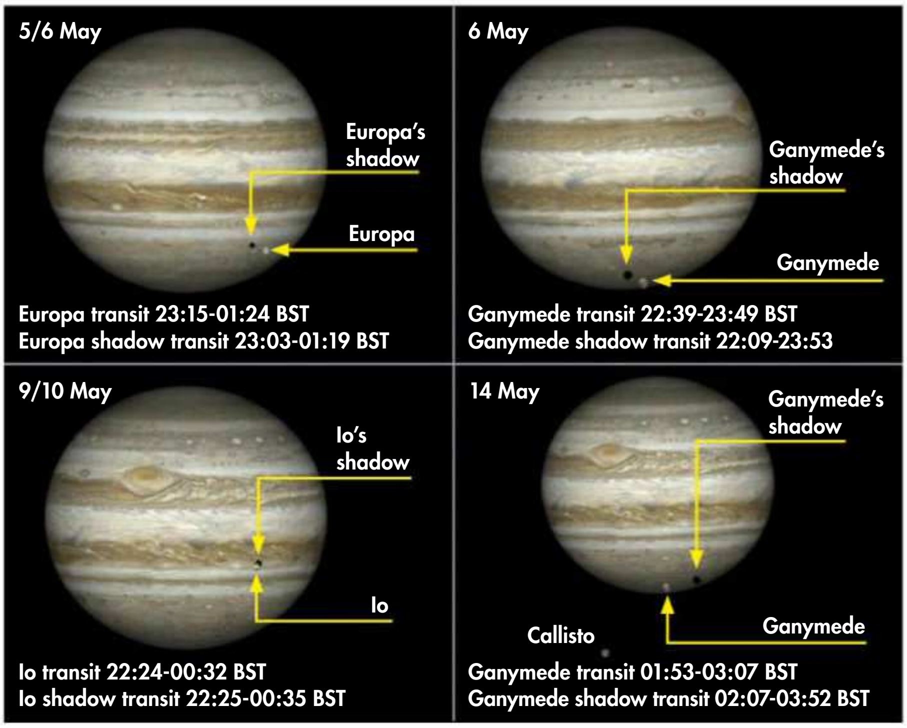
WHEN: 2, 5, 6, 8, 9, 13, 14 & 16 May

Among Jupiter's extended family of nearly 70 moons, only four can be easily seen through amateur telescopes. These are the Galilean moons, Io, Europa, Ganymede and Callisto, so called because they were first identified by Galileo in 1610.

Over time their star-like points flit back and forth either side of Jupiter's disc. When they approach the disc from the west they are on the far side of their orbit relative to Earth and will pass behind Jupiter's giant globe or into the planet's shadow. When they approach from the east they pass in front of Jupiter, casting dark shadows on the planet's atmosphere below. One exception to this is Callisto which has a large enough orbit to be able to pass above or below Jupiter when the planet's small axial tilt is inclined enough.

For much of the time the Galilean moons and their shadows appear well separated from one another. This changes near opposition when Jupiter is on the opposite side of the sky to the Sun. Before opposition a moon's shadow appears to the west of it, preceding the moon across the planet's disc. After opposition the shadow follows the moon to the east of it. At opposition, the moon and shadow line up, crossing Jupiter's disc in unison.

Typically this alignment isn't perfect because a line from the shadow through the moon doesn't directly point at Earth. Normally this line points either above or below our planet resulting in the moon's opposition shadow appearing above or below the moon. Catching a moon and shadow transit at opposition is a matter of luck as a small offset in time either side of opposition makes a big difference to the appearance of the pairing.



▲ **Some of the Galilean satellite and shadow transits visible around opposition. South is up**

There are a number of good examples of shadow transits this month occurring before and after 9 May, which is the date of Jupiter's opposition. On **2 May** Io can be seen chasing its shadow from 20:31 BST (19:31 UT). On **5 May** it's Europa's turn to do the same thing from 23:03 BST (22:03 UT).

A more impressive moon and shadow transit occurs on **6 May** when Ganymede can be seen chasing its shadow from 22:09 BST (21:09 UT). On **8 May**, just before opposition, Io's transit at 03:56 BST (02:56 UT) sees the moon virtually on top of its shadow. The end of this event occurs in daylight with Jupiter close to setting. A similar transit, again involving Io, occurs on **9 May** from 22:24 BST (21:24 UT).

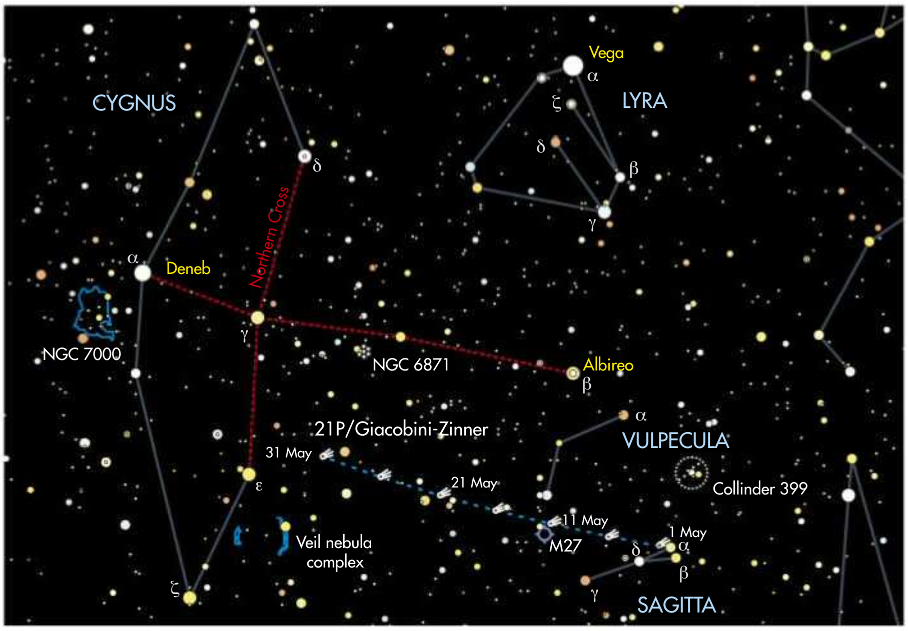
On **13 May** Europa's transit from 01:29 BST (00:29 UT) will see the moon preceding its shadow and another nice symmetry of events occurs after this with Ganymede also preceding its shadow from 01:53 BST (00:53 UT) on **14 May**. Io can once again be seen preceding its shadow on **16 May** at 23:08 UT.

Io in particular can be tricky to spot in transit visually. It stands out well if using an IR-pass filter fitted to a monochrome camera (inset)

PETE LAWRENCE X 4

Comet 21P/Giacobini-Zinner

WHEN: Throughout May, as described



▲ Path of comet 21P/Giacobini-Zinner through May. Positions correct for 01:00 BST on dates shown

Comet 21P/Giacobini-Zinner is currently a rather faint object tracking through the summer constellations of May's early morning sky. It passes Earth by just 0.39 AU next month but despite this is only expected to reach 11th magnitude. Things should improve later in the year when 21P may become bright enough to be seen with the naked-eye and, more importantly for the UK, will be well-positioned in the sky.

Back to this month and the comet starts its apparent journey against the background stars in the constellation of Sagitta, the Arrow. It should be around mag. +14.4 at this time so rather faint for visual detection but certainly a target for photography. It's conveniently located close to the mag. +4.4 star Alpha (α) Sagittae at 01:00 BST (00:00 UT) on 1 May.

Next 21P tracks through to Vulpecula passing between the mag. +7.9 open cluster NGC 6830 and mag. +7.4 planetary nebula M27 – the Dumbbell Nebula – on the night of 10/11 May. It remains relatively close to M27 on 11/12 May providing a reasonably good photographic opportunity to catch comet and nebula together in the same shot, despite the comet's dim 14th magnitude status.

Now the comet tracks north through Vulpecula and into Cygnus. It ends the month at mag. +12.8 lying 5° west-northwest of the vast supernova complex known as the Veil Nebula.

This area of sky is rich in background stars thanks to the Milky Way. If you continue to follow 21P as it tracks up across Cygnus's eastern wing, its most exciting encounter will come at the end of June when it skirts the eastern edge of NGC 7000, the North America Nebula.

Noctilucent cloud season is open

WHEN: From the last week of May, 90-120 minutes after sunset or a similar time before sunrise

The end of May is traditionally identified as the start of the Northern Hemisphere's noctilucent cloud season. Noctilucent clouds (NLCs), are high-altitude ice clouds which form in a narrow layer within the mesosphere, 82km up. At that altitude any NLCs present are able to catch the Sun's rays even when the Sun appears below the horizon from the ground. As they are thin, their visibility is delicate and the Sun has to be below the horizon – typically between 6° and 16° – for the sky to be dark enough for them to appear.

As they reveal their wispy presence by reflecting sunlight, noctilucent clouds normally make their evening debut low above the northwest horizon between 90-120 minutes after sunset. They make a similar appearance low above the northeast horizon a similar period before sunrise. If there, they appear to glow against the darkness of the night sky with any normal, tropospheric clouds appearing dark and silhouetted against them. They often appear electric blue in colour and exhibit delicate network-like structures.

Although there can be no guarantee that there will be any displays at all, it's worth getting into the habit of checking for noctilucent clouds early on in the season. This way you will be nicely trained for observing throughout the height of the season during June and July.

Tropospheric clouds are lower in the atmosphere than noctilucent clouds and so appear dark against the eerie glow of the NLCs

THE NORTHERN HEMISPHERE IN MAY

KEY TO STAR CHARTS

Arcturus	STAR NAME
PERSEUS	CONSTELLATION NAME
	GALAXY
	OPEN CLUSTER
	GLOBULAR CLUSTER
	PLANETARY NEBULA
	DIFFUSE NEBULOSITY
	DOUBLE STAR
	VARIABLE STAR
	THE MOON, SHOWING PHASE
	COMET TRACK
	ASTEROID TRACK
	STAR-HOPPING PATH
	METEOR RADIANT
Circlet	ASTERISM
	PLANET
	QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

N E S W — COMPASS AND FIELD OF VIEW

MILKY WAY

CHART: PETE LAWRENCE

WHEN TO USE THIS CHART

1 MAY AT 01:00 BST
15 MAY AT 00:00 BST
31 MAY AT 23:00 BST

On other dates, stars will be in slightly different places due to Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

HOW TO USE THIS CHART

1. **HOLD THE CHART** so the direction you're facing is at the bottom.
2. **THE LOWER HALF** of the chart shows the sky ahead of you.
3. **THE CENTRE OF THE CHART** is the point directly over your head.

SUNRISE/SUNSET IN MAY*

DATE	SUNRISE	SUNSET
1 May 2018	05:36 BST	20:40 BST
11 May 2018	05:17 BST	20:57 BST
21 May 2018	05:01 BST	21:13 BST
31 May 2018	04:49 BST	21:27 BST

MOONRISE IN MAY*

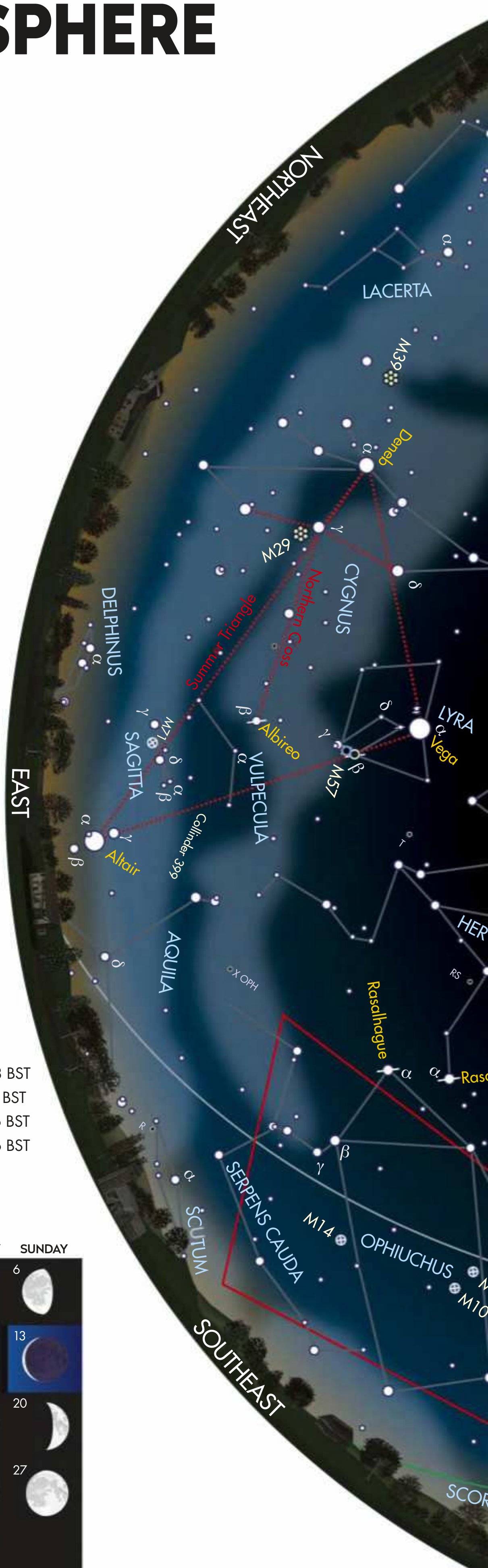
MOONRISE TIMES

01 May 2018, 22:12 BST	17 May 2018, 06:58 BST
05 May 2018, 01:08 BST	21 May 2018, 11:21 BST
09 May 2018, 03:27 BST	25 May 2018, 16:26 BST
13 May 2018, 04:53 BST	29 May 2018, 21:06 BST

*Times correct for the centre of the UK

LUNAR PHASES IN MAY

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15 NEW MOON	16	17	18	19	20
21	22	23	24	25	26	27
28	29 FULL MOON	30	31			



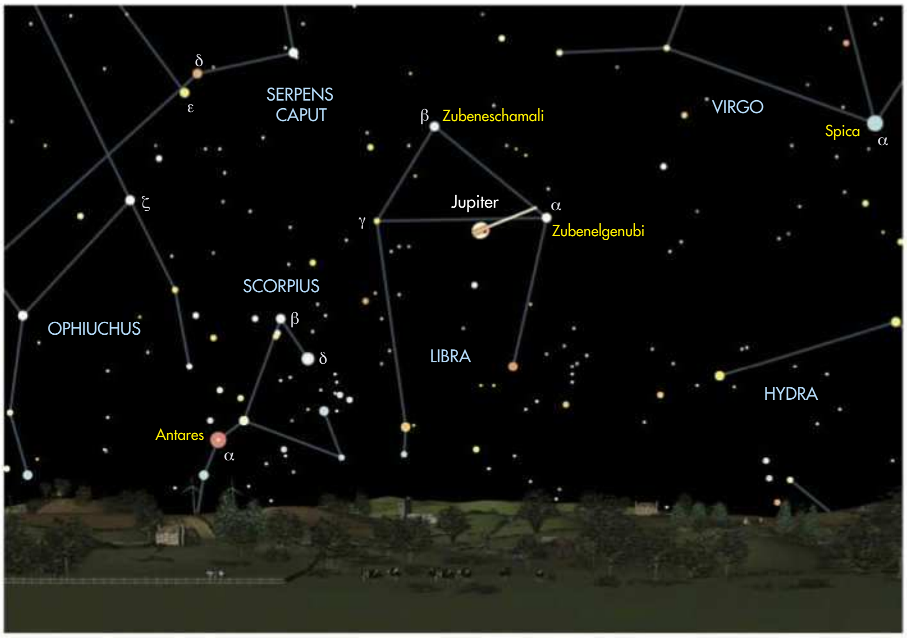
YOUR BONUS CONTENT
Paul and Pete's Virtual Planetarium

THE **PLANETS**

PICK OF THE MONTH

Jupiter

BEST TIME TO SEE: 9 May, 01:10 BST (00:10 UT)
ALTITUDE: 21°
LOCATION: Libra
DIRECTION: South
FEATURES: Complex, banded atmosphere; Great Red spot; Galilean moons



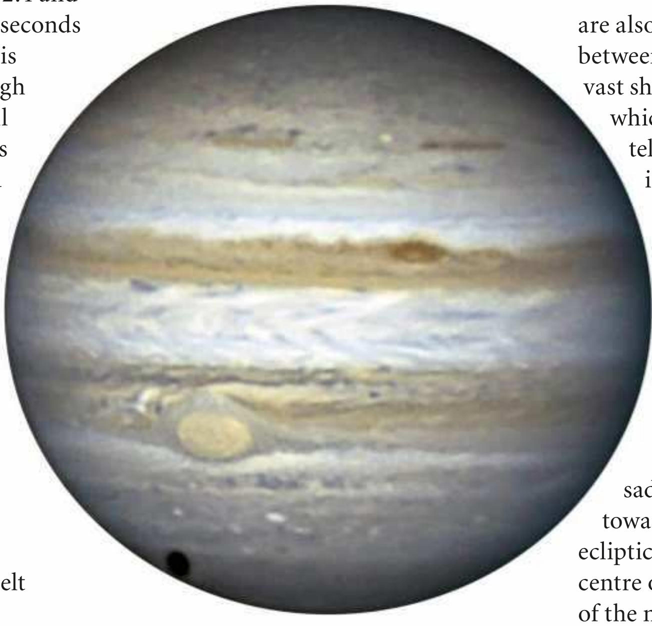
▲ Jupiter will reach opposition in Libra on 9 May and will be highest in the sky around 01:00 BST

Jupiter is at opposition on 9 May, a time when the planet is in the opposite part of the sky to the Sun. This means that May is an excellent month to observe Jupiter. On 9 May, Jupiter shines at mag. –2.4 and presents a disc that appears 44 arcseconds across. At this apparent size there is plenty of detail up for grabs through the eyepiece of a telescope. A small scope will clearly show the planet's oblate shape, the result of its rapid rotation. In addition, its two main belts are easily seen either side of the Jovian equator.

The Great Red Spot is one of the observing highlights on Jupiter and can be seen through a telescope with a 100mm or greater aperture. The spot represents a persistent storm in Jupiter's atmosphere. The Jovian atmosphere is very dynamic. For example, earlier this year, a storm outbreak in the south temperate belt (STB) was observed.

The four largest moons of Jupiter – Io, Europa, Ganymede and Callisto – are also fascinating to watch. As they pass between Jupiter and the Sun they cast vast shadows on the atmosphere below, which can be seen with relatively small telescopes. Before opposition it's interesting to watch how the moons chase their shadows, catching up with them on opposition day and then leading them after opposition. There are a number of such events visible this month (see pages 50, 51 and 52 for more information), which spectacularly illustrate the effect.

From the UK, Jupiter is now sadly losing altitude as it heads east towards a more southerly part of the ecliptic. Its maximum height from the centre of the UK is around 21°. By the end of the month, Jupiter will have nudged west enough to sit within a degree of Zubenelgenubi (Alpha (α) Librae).

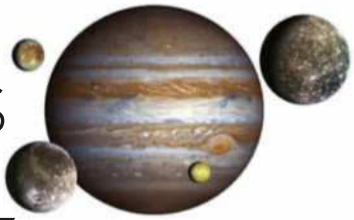


▲ Despite its fame, the Great Red Spot is surprisingly tricky to spot with smaller scopes

PETE LAWRENCE X 3

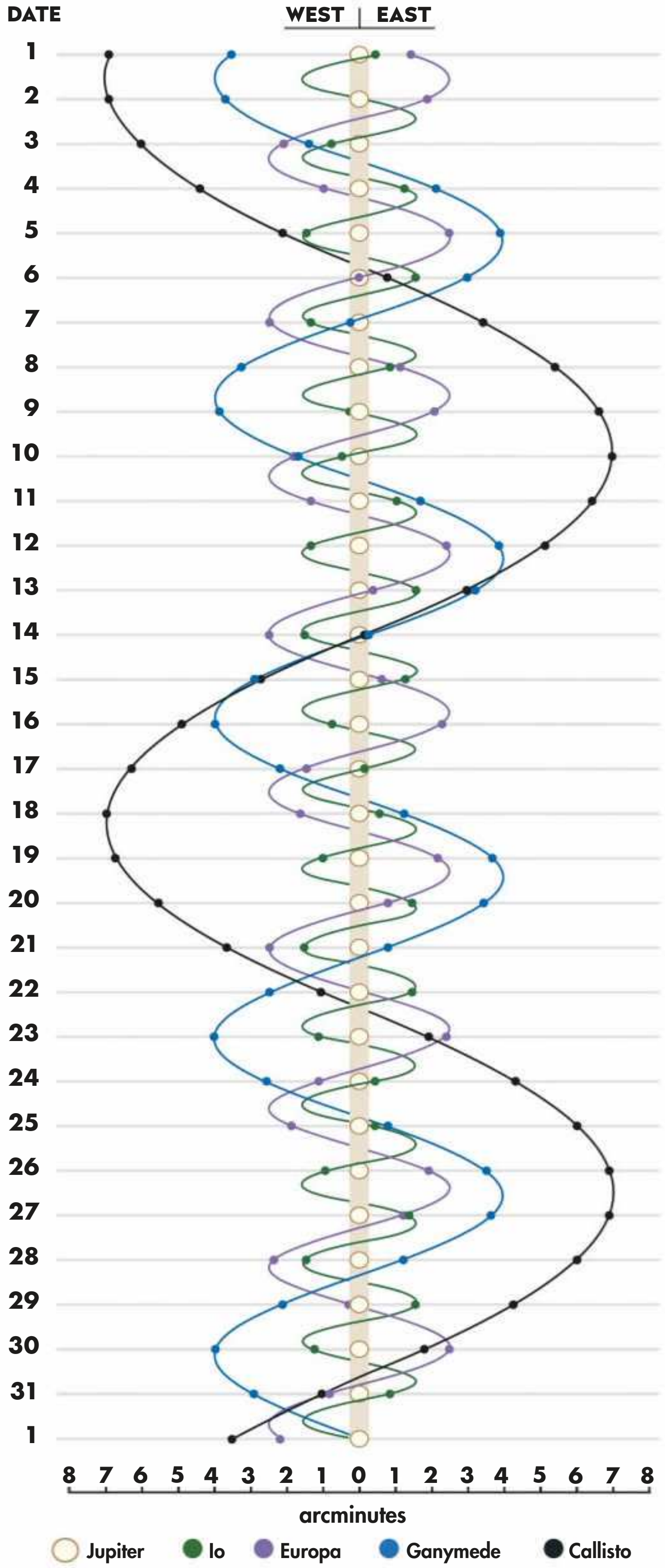
THE PLANETS IN MAY

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



JUPITER'S MOONS MAY

Using a small scope you'll be able to spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date on the left represents 00:00 UT.



Mercury

Mercury is not well positioned this month, appearing as a morning object barely creeping above the east-northeast horizon at sunrise.

Venus

Best time to see: 31 May, 22:00 BST (21:00 UT)
Altitude: 16°
Location: Gemini
Direction: West-northwest

Over recent weeks Venus has become a familiar sight in the western sky after sunset and this is set to continue throughout May. The planet's position does become slightly less optimal throughout the month owing to the decreasing angle between the horizon and the ecliptic. However, this is offset to a degree by Venus increasing its apparent distance from the Sun. At mag. –3.8, Venus appears very bright and able to shine through even bright dusk skies. On 17 May, Venus will appear 5° north of a lovely 7%-lit waxing crescent Moon. On 21 May, Venus appears less than a degree from the open cluster M35 in Gemini. Sadly, the bright evening twilight will reduce the visibility of this mag. +5.5 cluster. By 31 May, Venus will set nearly three hours after the Sun. When viewed through a telescope on this date the planet presents a 13 arcsecond disc, 80% illuminated.

Mars

Best time to see: 31 May, 03:30 BST (02:30 UT)
Altitude: 12° (Low)
Location: Sagittarius
Direction: South-southeast

Mars is a morning object in Sagittarius at the start of the month and looks impressively bright – its magnitude now in negative values. On 1 May it shines away at mag. –0.4. Telescopically at the start of the month, it shows an 11-arcsecond disc, easily large enough to reveal surface detail. On 6 May, a 68%-lit waning gibbous Moon lies very close to Mars. The Red Planet crosses the border from Sagittarius into Capricornus mid-month, increasing in brightness all the while. By 31 May, Mars shines at mag. –1.2, appearing like a magnificent orange star amongst the dimmer stars that make up the triangular constellation of Capricornus. The planet's size is also on the increase so that by 31 May it will look 15 arcseconds across when viewed through a telescope.

Saturn

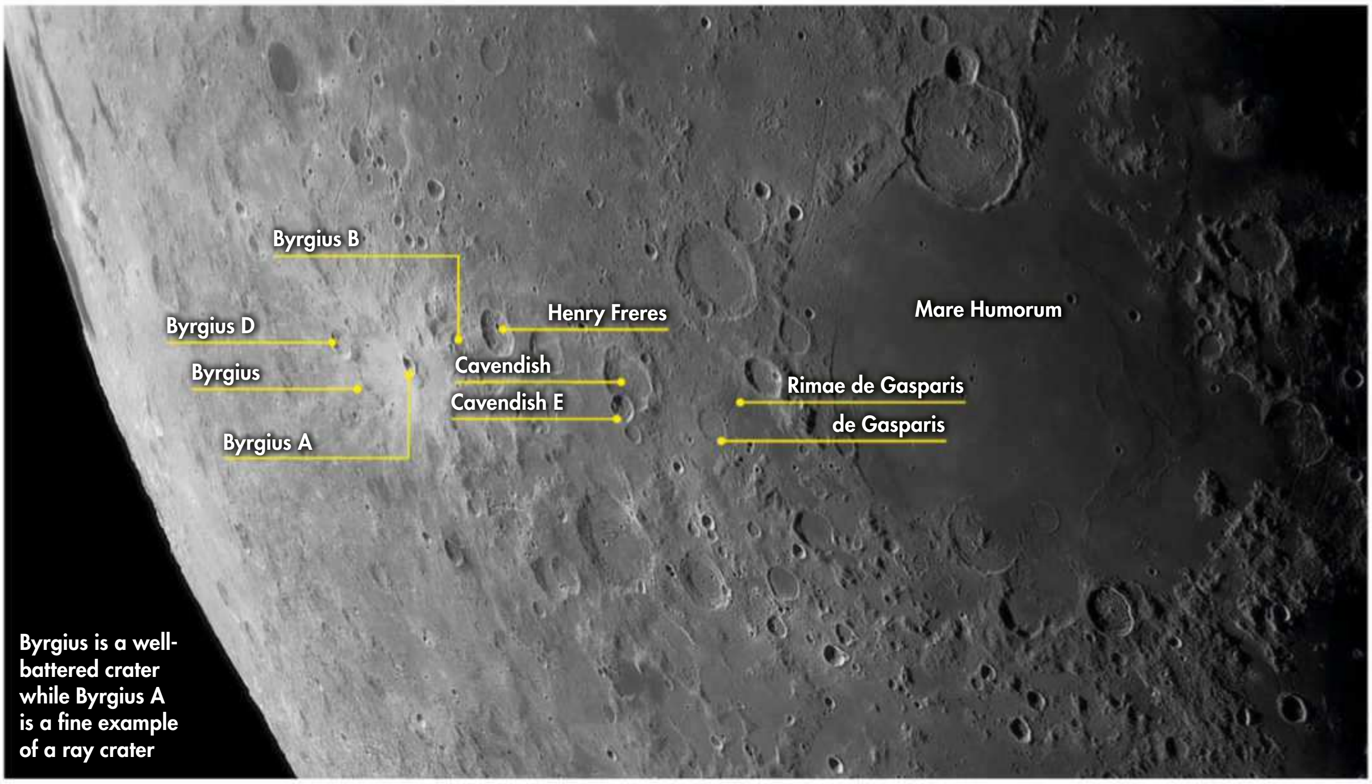
Best time to see: 31 May, 02:40 BST (01:40 UT)
Altitude: 14°
Location: Sagittarius
Direction: South

Saturn appears like a yellowish, mag. +0.7 star to the north of the Teapot asterism in Sagittarius at the start of the month. This is a good time to try and get a telescopic view of Saturn as its rings are currently nicely presented. From the UK, Saturn's altitude is challenged owing to it being in a position that keeps it low in the south. A bright gibbous Moon flits from the west to the east of Saturn on the mornings of 4 and 5 May. By the end of the month, mag. +0.6 Saturn makes it to a position due south in relative darkness. This brings Saturn to its highest point in the sky, which, from the UK at least, isn't that impressive. At its best, from the centre of the UK, Saturn only manages to attain a peak altitude of 14°.

On the evening of 31 May, the Moon makes a second visit to the planet. Look out for the sight of a 94%-lit waning gibbous Moon sitting 50 arcminutes to the north of Saturn on this date.

Not visible this month:
Uranus, Neptune

YOUR BONUS CONTENT Planetary observing forms

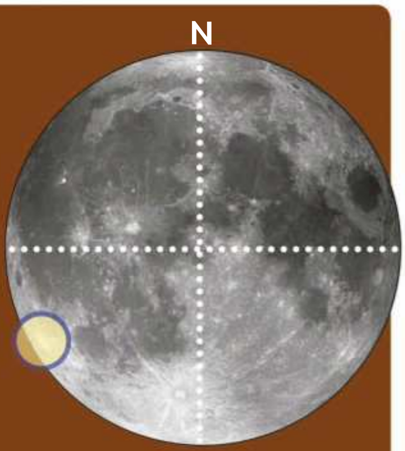


Byrgius is a well-battered crater while Byrgius A is a fine example of a ray crater

MOON**WATCH**

Byrgius

Type: Crater
Diameter: 88km
Longitude/latitude: 65.4° west, 24.7° south
Age: Between 3.85-3.92 billion years
Best time to see: Four days after last quarter (12-13 May) or five days after first quarter (28-29 May)
Minimum equipment: 50mm refractor



> ***"An old feature, its borders are irregular from multiple bombardments"***

Despite its impressive 88km diameter, **Byrgius** appears diminished because of its location on the Moon as seen from Earth. It's very close to the western limb making it appear foreshortened into an ellipse. Being an old feature, its borders are irregular from multiple bombardments. Towards the west, the rim rises to a height of around 2km and there are breaks in the rim to the north and south.

Equally as impressive are the two smaller craters that lie nearby. 19km **Byrgius A** is an excellent example of a ray crater, with bright ejecta emanating out of the impact zone for distances up to 400km across the lunar surface; it is on the Association of Lunar and Planetary Observers (ALPO) list of bright ray craters. On the opposite side of Byrgius is 27km **Byrgius D**, which appears to have a very sharp, well-defined rim that contrasts starkly with the eroded form of Byrgius itself.

Follow the line out from the centre of Byrgius, through ray crater Byrgius A, and the most distinctive feature you'll arrive at will be 41km **Henry Freres**. Midway between Henry Freres and Byrgius A is the less prominent form of 23km **Byrgius B**, which is striped by ejecta from Byrgius A. This is on the ALPO list of banded craters, features that exhibit radial bands across their inner walls. For a long time the origin of these bands was poorly understood, but it's now thought that many such bands are simply lines of contrasting ejecta from the impact that formed the crater.

This region of the Moon can be difficult to navigate under high illumination because of its lack of distinctive surface tonal variations. The most obvious feature is the 380km **Mare Humorum**, which lies 735km to the east (centre to centre). Roughly midway between the centre of Byrgius and the western shore of Mare Humorum is 56km **Cavendish**, defined by the 24km crater **Cavendish E**, which interrupts the southwest part of its rim.

Located 85km southeast of Cavendish is 30km **de Gasparis**. This is a fascinating area to study using a 200mm or larger telescope as it's criss-crossed by a number of fine rilles, collectively known as **Rimae de Gasparis**. Under oblique illumination, it is well worth taking your time studying this area, trying to figure out how far you can follow these narrow features. On average the Rimae de Gasparis are around 3km wide.

Being relatively close to the Moon's western limb, Byrgius is heavily influenced by the Moon's libration state. Libration is the collective term used to describe the apparent rocking and rolling action of the Moon's globe as seen from Earth. This is the result of the variation in the Moon's orbital speed around its elliptical orbit and the tilt of the orbit relative to Earth's orbit. Although Byrgius doesn't disappear around the western limb because of libration, it does get quite close and at such times presents an even narrower, highly foreshortened ellipse.

PETE LAWRENCE X 3

COMETS AND ASTEROIDS

Follow 15 Eunomia as its skims along the horizon to meet Centaurus

▲ **You need a flat, clear horizon for the best views of 15 Eunomia**

Asteroid 15 Eunomia was discovered by Annibale de Gasparis in 1851 and is the largest known S-type, or silicaceous, asteroid – these are characteristically metallic, reflective and bright. In May, Eunomia will hover around mag. +10, making it an easy target for a small telescope or large binoculars. It reaches opposition on 8 May when it will appear as a mag. +9.8 dot in the north of Centaurus.

Centaurus isn't normally associated with northern hemisphere viewing but it's a glorious sight to behold from more southerly climes. However, the extreme northern part of the constellation just manages to rise above the UK's southern horizon. In order to see it, you'll need a good, flat horizon in this direction. Aim to view from 01:00 BST (00:00 UT) at the start of the month. A bright, almost full Moon will spoil the show during early May and a severe lack of night will make things harder at the end of the month. Ironically this is when the asteroid will be climbing higher in the sky. The best time to catch Eunomia will be mid-month from around 00:00 BST (23:00 UT).

At 330kmx245kmx205km Eunomia is between the eighth and 12th largest asteroid in the main-belt between Mars and Jupiter. It's not possible to rank accurately as there's uncertainty about some diameters. Its orbit swings from 2.149 AU out as far as 3.138 AU from the Sun. The orbit is chaotic and will change randomly over time because of the gravitational influence of the planets. It currently takes 4.3 years to complete one orbit and rotates once on its axis every 6.1 hours.

It can appear as bright as mag. +7.9 during favourable oppositions, with an angular diameter of 0.29 arcseconds. Its mass is estimated at slightly in excess of 1% of the entire asteroid belt at 3.12x10^{19}kg.

STAR OF THE MONTH

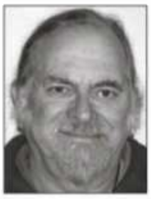
Is there something green about Beta (β) Librae?

The star Beta (β) Librae, sits at the top of the fairly indistinct constellation of Libra, the Scales. This is reasonably well positioned, low in the south at 02:00 BST (01:00 UT) on 1 May, 01:00 BST (00:00 UT) on 15 May and 00:00 BST (23:00 UT) on 31 May. At mag. +2.6 it is a middling brightness star that goes by the wonderful name of Zubeneschamali, meaning 'northern claw'. Its counterpart is mag. +2.8 Alpha (α) Librae or Zubenelgenubi, which means 'southern claw'. At the moment, the bright planet Jupiter is located really close to Zubenelgenubi. Although it seems odd to have two 'claws' in a constellation representing a set of balance scales, this makes more sense when it's revealed that Libra used to be part of neighbouring Scorpius, the Scorpion.

Zubeneschamali is a B8V dwarf star with a surface temperature around 12,300K. It's around 130 times more luminous and 4.9 times larger than our Sun, with 3.5 times the mass. It also spins over 100 times faster than the Sun, with a rotational velocity of 250 km/s. At an estimated age of 80 million years, this is a hot, young star. Its temperature suggests it should shine with a blue-white colour and to most observers this is indeed the case.

However, in the past Zubeneschamali has been described as green in hue. If this were true Zubeneschamali would be the only green naked-eye star in the sky. Green is an odd colour for a star because, even if a star's output were to peak in the green part of the spectrum, the narrow range of wavelengths from 500-570nm, which appear as green, are easily swamped by the wide yellow and blue wavelengths either side. Consequently, to the human eye, such stars tend to appear white. Does Zubeneschamali buck the trend? Pop outside and judge for yourself.

▲ **Small variations in Beta (β) Librae's magnitude hint at an as-yet undiscovered companion star**



STEPHEN TONKIN'S

BINOCULAR TOUR

A double double and a tricky trio of galaxies in Leo are among this month's highlights

☑ Tick the box when you've seen each one

1 MELOTTE 111

10x 50 Let's start our tour with one of the finest celestial sights for binoculars, Melotte 111. It extends for nearly 6° and fills the view of small and medium binoculars. You can see it with your naked eye as a misty patch between Cor Caroli (Alpha (α) Canum Venaticorum) and Denebola (Beta (β) Leonis). Gamma (γ) Comae Berenices is at the apex of an inverted 'V' of the cluster's brighter stars. Melotte 111 is unusual in having no stars fainter than mag. +10.5. ☐ **SEEN IT**

2 28 & 29 COMAE AND STRUVE 1678

10x 50 5° northwest of Vindemiatrix (Epsilon (ε) Virginis) is a pair of white stars separated by half a degree and orientated approximately north-south. The fainter, southerly one is 28 Comae, the brightest of a little parallelogram of stars. 29 is the brightest of a triple star group. Its brighter (mag. +8.6) companion is 5 arcminutes back towards 28 and the fainter (mag. +9.9) one is an arcminute closer, an easy split if your sky lets you see stars that faint. Also visible, a degree to the west of 29, is Struve 1678, a slightly harder split at 38 arcseconds. ☐ **SEEN IT**

3 M49

15x 70 Our first galaxy is an elliptical radio galaxy, M49. If you locate Rho (ρ) Virginis (mag. +4.9) and place it on the northeast of your field of view, on the opposite side you should find a pair of 6th magnitude stars, just over a degree apart and orientated southeast-northwest. M49 is a small (9 x 7.5 arcminutes), slightly oval patch of light between these two stars, very slightly nearer the more southerly one. Using averted vision, you can see lots of galaxies in this region of sky, mostly in the direction of Melotte 111. ☐ **SEEN IT**

4 TAU (τ) AND 83 LEONIS

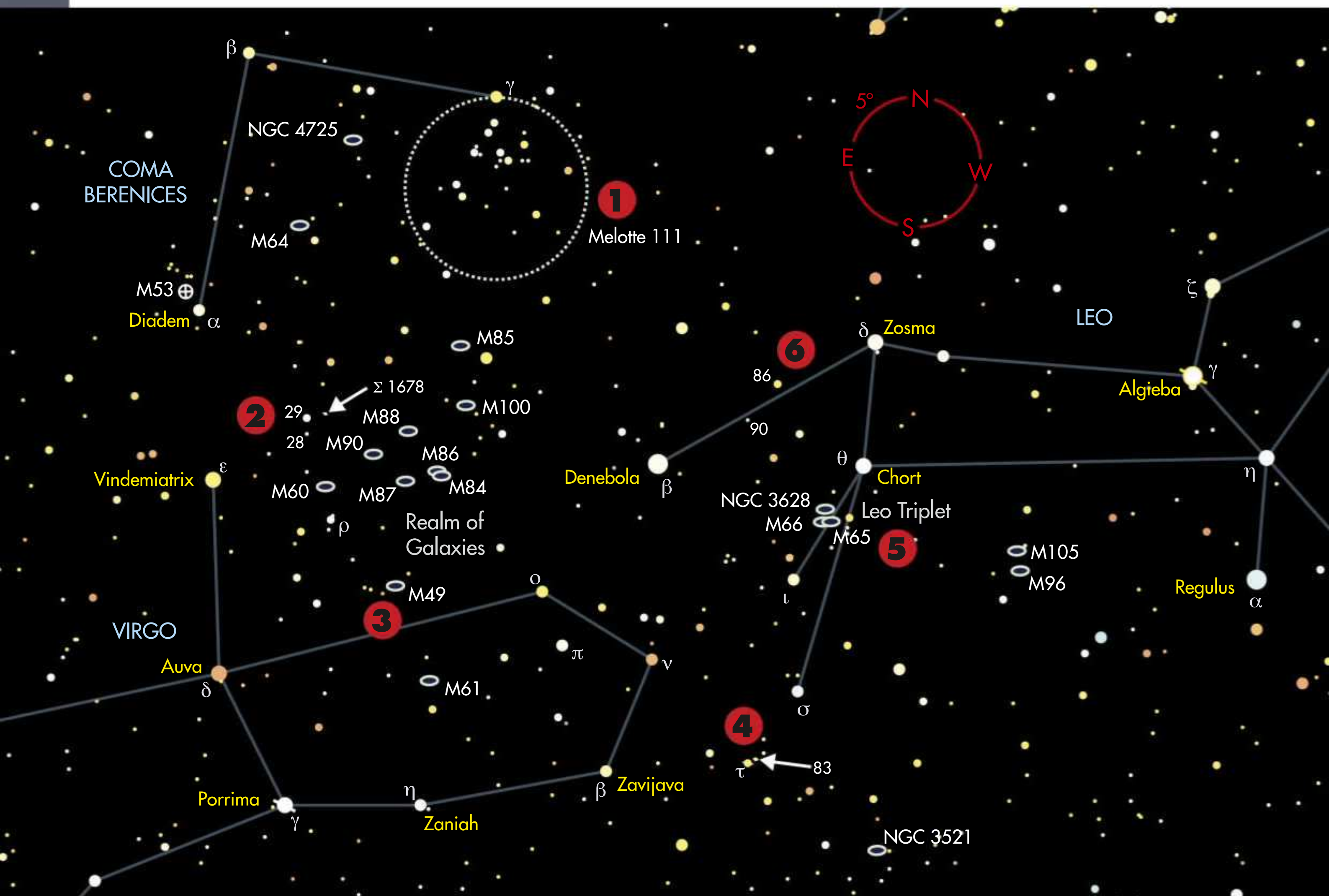
10x 50 Did you know that Leo has 'double double'? If you extend a line from Zania (Eta (η) Virginis) to Zavijah (Beta (β) Virginis) a further 6°, mag. + 4.9 Tau (τ) Leonis is the brightest star in the field of view. A third of a degree northwest is its mag. +6.5 companion, 83 Leonis. Look carefully and you'll see that each of these is a double star with a mag. +7.5 companion. ☐ **SEEN IT**

5 LEO TRIPLET

15x 70 You may need to wait until Leo is high in the southern sky before you can observe our second galactic target, a trio of galaxies that is a challenge in anything other than a dark, very transparent sky. If you put mag. +3.3 Chort (Theta (θ) Leonis) just outside the northwest of the field of view of 15x70 binoculars, the galaxies will be in the centre. You may need averted vision at first, but they soon become easier to see, although you will still need averted vision to discern the different shape of NGC 3628. ☐ **SEEN IT**

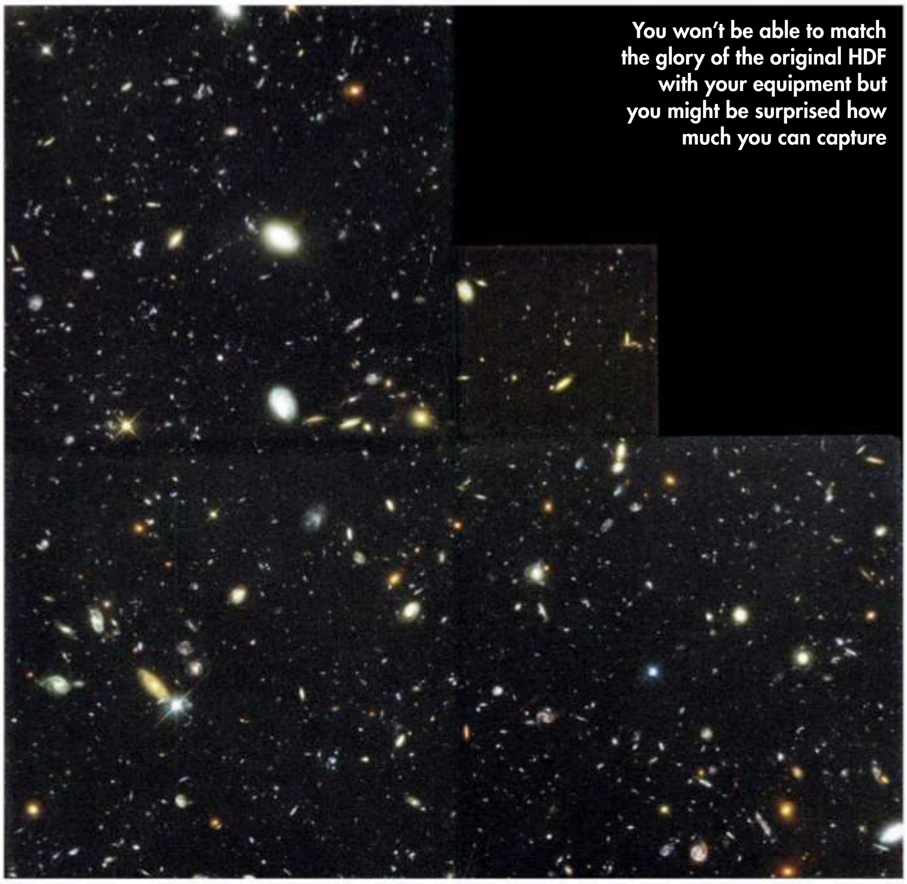
6 86 LEO REGION

10x 50 Locate the orange-yellow mag. +5.6 86 Leonis between Denebola (Beta (β) Leonis) and Zosma (Delta (δ) Leonis), and compare its colour to hot blue-white 90 Leonis 2° back towards Denebola. Return your attention to 86, and note the curved string of 7th and 8th magnitude stars extending 3° eastward. The nearest one to 86 is FV Leonis, an orange, long-period variable star; the most distant is blue-white FW Leonis, whose brightness variation is too tiny to be visible in binoculars. ☐ **SEEN IT**



THE SKY GUIDE **CHALLENGE**

Just how much of the Hubble Deep Space Field can you capture with home equipment?



You won't be able to match the glory of the original HDF with your equipment but you might be surprised how much you can capture

The Hubble Deep Field (HDF) is an amazing image which brought home how incredible our Universe really is. It consisted of 342 separate exposures taken by the Hubble Space Telescope (HST) over 18-28 December 1995. The combined result produced an unprecedented look into deepest space. The target area was a rather bland section of Ursa Major approximately one 24-millionth the area of the entire sky. Despite measuring just 2.6 arcminutes across, around 3,000 distant galaxies fill the frame.

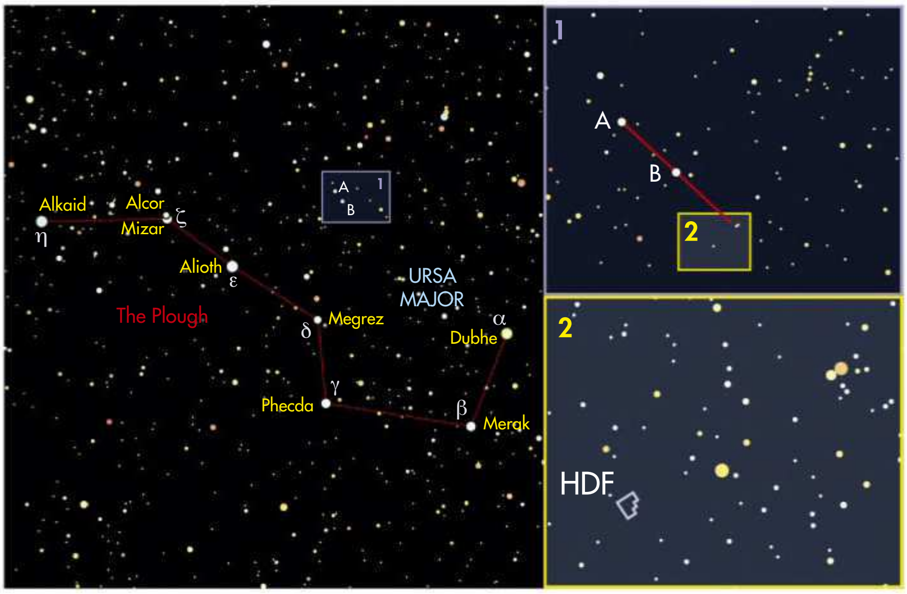
The original HDF target area lies just north of the Plough asterism. As this is currently well placed in the UK's night sky, we thought trying to replicate the HDF would be a good challenge. Okay, unless you own your own space telescope, it's not going to happen, but you should be able to record some of the brighter objects visible in the original image. This is best-suited to a CCD/telescope combination but other combinations may work too. And it's not limited to large apertures either, so any setup should reveal something of the HDF.

The first issue is locating the correct bit of sky. As it was specifically chosen because it looked empty, you'll need to employ a bit of star hopping to get there. Use stars Alioth and Megrez as your starting point. From there navigate to the two 6th magnitude stars we've labelled A (HIP 62402) and B (HIP 61936, or 76 Ursae Majoris). Use these as shown to navigate to the correct bit of sky.

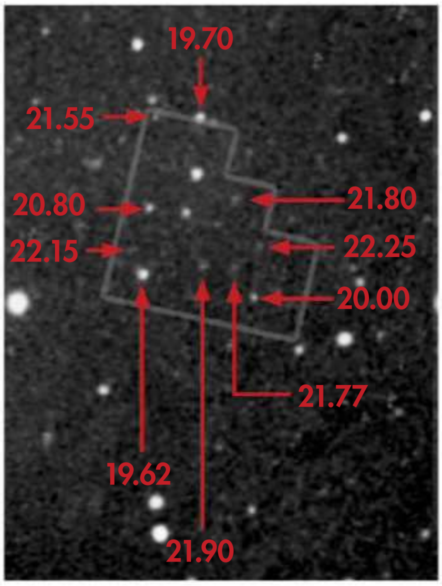
The Hubble Deep Field covers an area 2.6x2.6 arcminutes, roughly 1/12th the apparent diameter of the Moon. A setup covering an image area of 30 arcminutes or smaller is recommended and you'll need good tracking or preferably autoguiding to avoid long exposure trailing. We suggest exposure times in excess of 900 seconds.

As ever, experiment with your exposures to see what works best for you. Image registration and stacking will definitely help smooth out some of the noise that gets in the way and we recommend a full calibration sweep of darks, flats and bias correction.

The original HDF revealed how vast our Universe truly is. Your own version of the HDF will reveal how much of that Universe is available for even modest equipment to image. Don't forget to send your results in to our Hotshots gallery (see page 28).

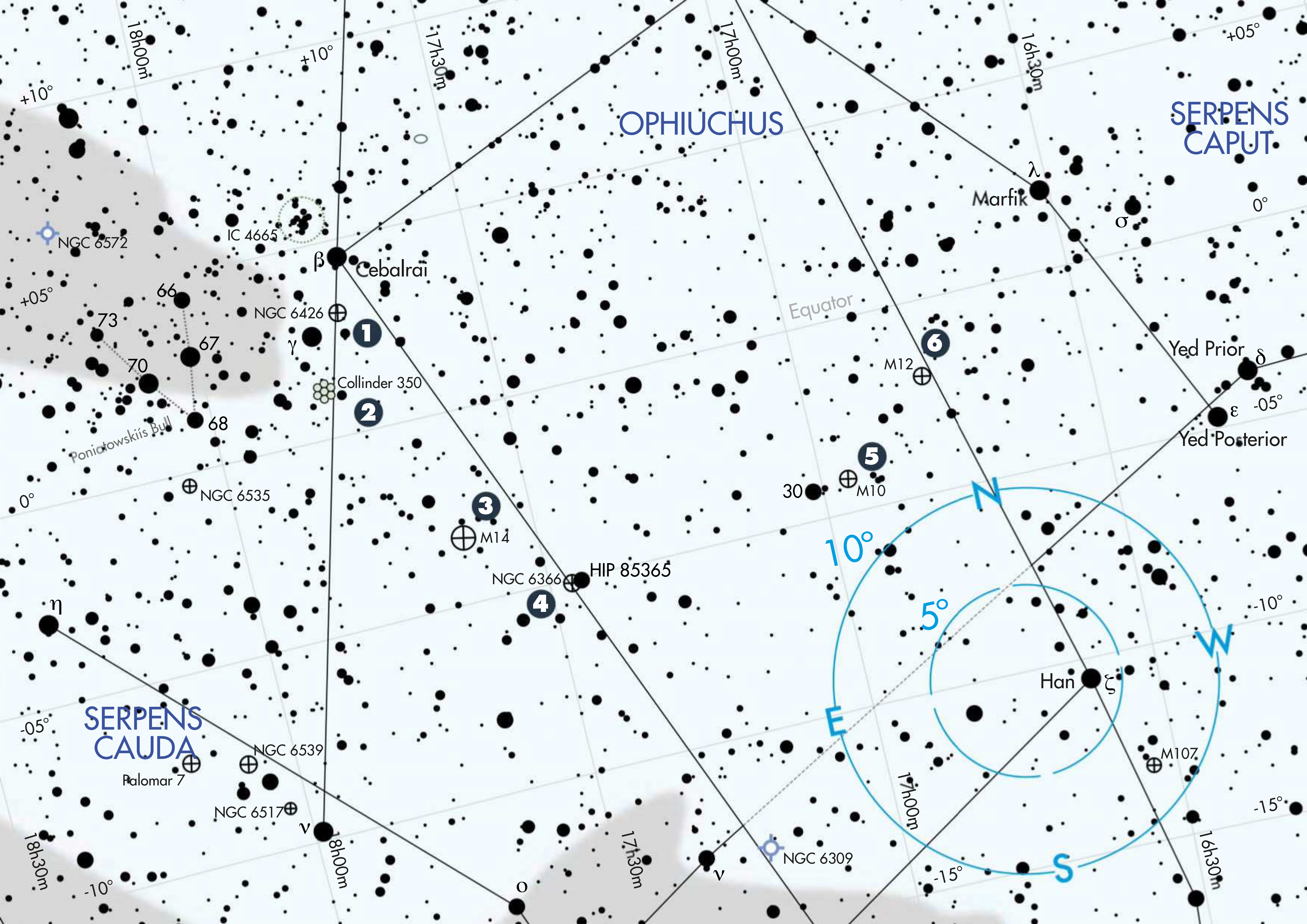


▲ Locate the two stars labelled A and B to help you focus in on the correct HDF area



▲ The HDF field imaged with a 4-inch refractor and CCD camera showing features down to at least mag. +22.25

PETE LAWRENCE X 3, R. WILLIAMS (STSCI) THE HUBBLE DEEP FIELD TEAM AND NASA



OPHIUCHUS
SERPENS CAPUT
SERPENS CAUDA
Marfik
Cebalrai
Yed Prior
Yed Posterior
Han
Equator
IC 4665
NGC 6572
NGC 6426
Collinder 350
Poniatowski's Bull
NGC 6535
M14
NGC 6366
HIP 85365
M12
M10
30
M107
NGC 6309
NGC 6539
NGC 6517
Palomar 7
66
67
68
70
73
β
γ
λ
σ
δ
ε
ζ
η
ν
ν
ο
1
2
3
4
5
6
5°
10°
N
E
S
W
18h00m
17h30m
17h00m
16h30m
18h30m
+10°
+05°
0°
-05°
-10°
-15°

DEEP-SKY TOUR

Some elusive clusters lurk in Ophiucus but they are worth searching out

☑ Tick the box when you've seen each one

1 NGC 6426

This month's objects can be found in a strip of sky passing across the middle of the large constellation of Ophiuchus, the Serpent Bearer. The first object of interest on our list is the most northerly in this month's tour, located 1.5° to the south and slightly east of mag. +2.8 Cebalrai (Beta (β) Ophiuchi). NGC 6426 is a faint, mag. +11.1 globular cluster which best suits apertures over 200mm. Even then, this elusive cluster can be a struggle to spot, appearing merely as a gently glowing patch against the dark background sky. Matters don't improve much through a 300mm scope, with the cluster appearing as a weak smudge of light with uneven brightness and no significant resolution to speak of. ☐ **SEEN IT**

2 COLLINDER 350

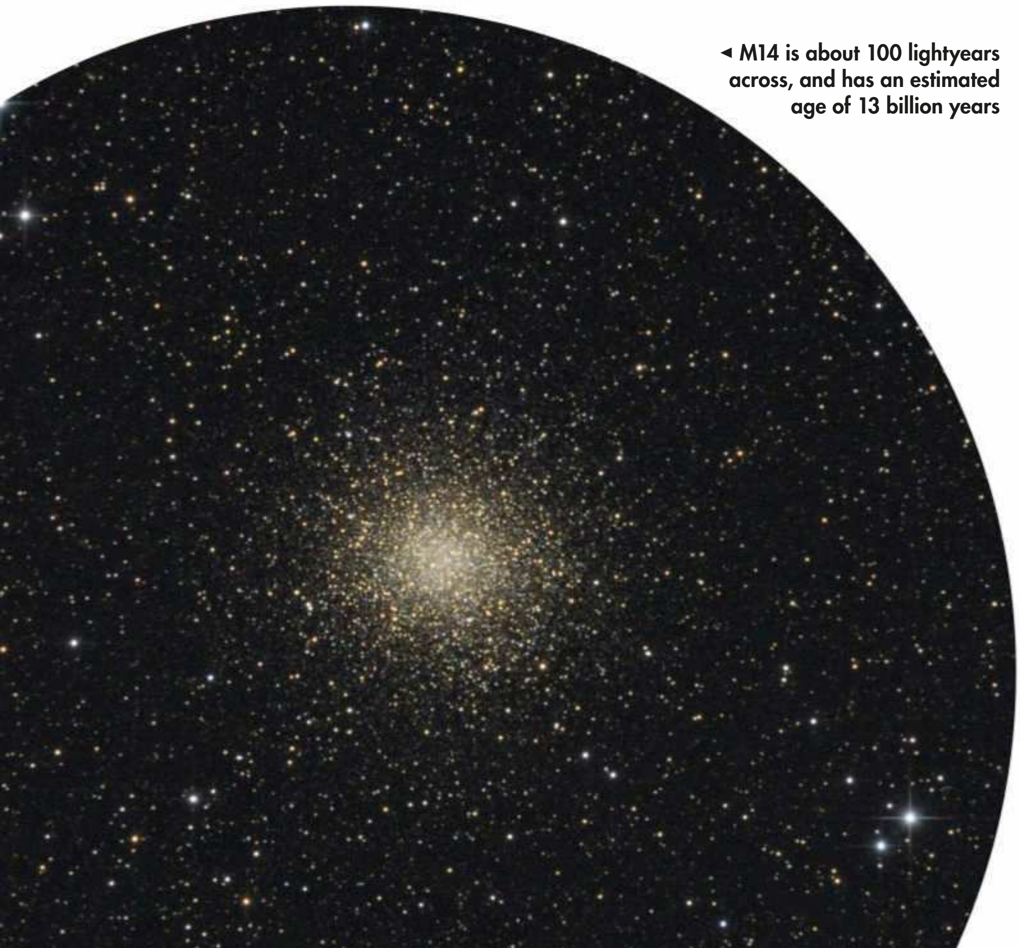
Extend the line from Cebalrai through NGC 6426 and keep going for the same distance again to arrive at another rather ill-defined object, the open cluster Collinder 350. This is another tricky target because it falls apart under magnification owing to its diffuse nature. There are about 15 viewable stars associated with the cluster, and – as suggested – the best way you're going to get to see these is by using a very low power. A large number of background stars in this area also helps Collinder 350 camouflage itself into the background. The cluster has a large apparent diameter of around half-a-degree, roughly equivalent to the apparent size of the full Moon. ☐ **SEEN IT**

3 M14

Our next target this month is the far more promising mag. +7.6 globular cluster, M14. Located at a distance of 30,300 lightyears, this cluster appears off to the east of the giant box shape that forms the body of the serpent bearer. One way to find M14 is to place the mag. +3.2 star Eta (η) Ophiuchi centrally in the field of view of a low-power eyepiece and then swing the telescope west in RA by 00h 44m (11°). A 150mm telescope at high power reveals the cluster to have a distinctly mottled texture. Through larger apertures you can begin to discern its elongated shape with a few of the member stars starting to be resolved at powers over 200x. ☐ **SEEN IT**

4 NGC 6366

Our next stopping-off point is the globular cluster NGC 6366, which at mag. +8.9 lacks the brilliance of M14. It lies 16 arcminutes east of the mag. +4.5 star, HIP 85365. The faint cluster also has a 9th magnitude star located just to the west. A 150mm telescope reveals an 11th magnitude pair of stars to the south-southwest of the cluster's core. Small instruments aren't likely to pick up much in the way of resolution when it comes to NGC 6366, instead revealing the cluster as a gentle glow. A 250mm scope at 250x power starts to resolve members against what looks like a more mottled background glow. Larger instruments continue this progression, creating the impression of a smattering of evenly spread faint stars against a mottled background almost 10 arcminutes across. ☐ **SEEN IT**



◂ **M14 is about 100 lightyears across, and has an estimated age of 13 billion years**

THIS DEEP-SKY TOUR HAS BEEN AUTOMATED

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

5 M10

Next we head westward for our penultimate target, another globular cluster known as M10, which lies at a distance of 14,300 lightyears from Earth. This particular cluster sits a degree west of 30 Ophiuchi, a mag. +4.8 star located southwest of the centre of the giant box shape representing the Serpent Bearer's body. Unlike most of our previous targets on this tour, mag. +6.7 M10 resolves fairly well through even a 150mm scope, with many of the stars appearing superimposed over the glowing cluster background. Larger instruments only improve the view, revealing an elongation in the cluster's core. Through a 200mm instrument, M10 appears with an apparent diameter of 10 arcminutes, with the well-defined core occupying approximately half this size. ☐ **SEEN IT**

6 M12

The end point for this month's journey is yet another globular cluster and fortunately for us, it's one that – at mag. +6.8 – finds itself at the brighter end of the spectrum. M12 lies 3.3° northwest of M10, the two objects often being cited as a pair. It's an easy small telescope object which appears less condensed than M10. Around 70 stars are resolved through a 150mm scope at 200x magnification. Larger apertures vastly increase the number of individual stars that you can see, with the number increasing into the hundreds through a 250mm instrument. The outlying stars are quite unevenly spaced in M12 compared to those around M10. M12's core also appears markedly smaller than M10's. ☐ **SEEN IT**

YOUR BONUS CONTENT

Print out this chart and take an automated Go-To tour

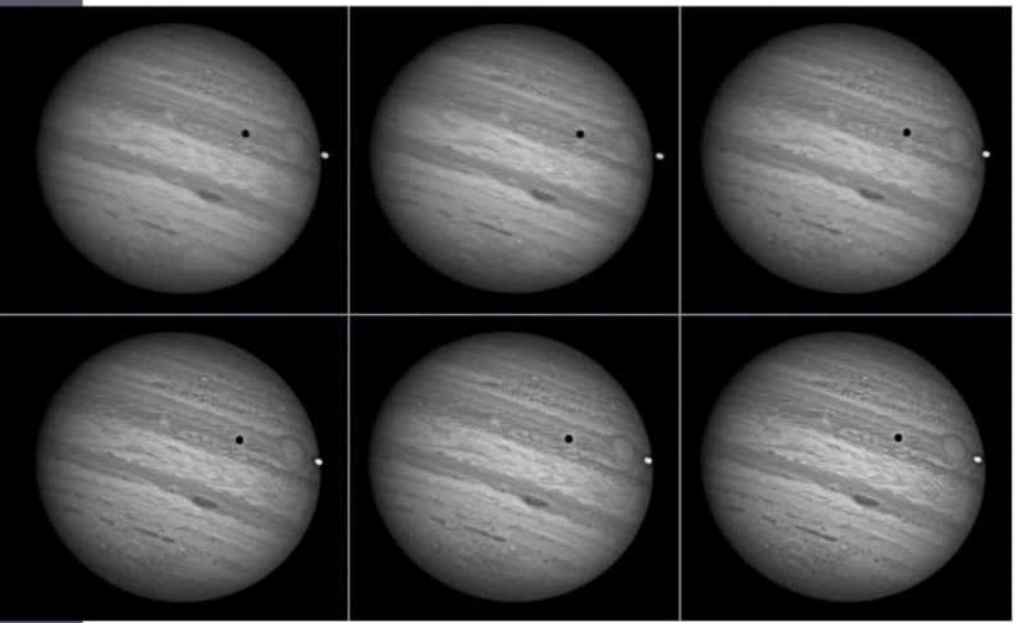
CHART: PETE LAWRENCE, PHOTO: BERNHARD HUBL/CCDGUIDE.COM

ASTROPHOTOGRAPHY

Creating a Galilean moon transit animation

RECOMMENDED EQUIPMENT

A high frame rate camera and a long focal length telescope over 3,000mm



▲ **A great way to observe the relationship between Jupiter and its moons is with an animation**

ALL PICTURES: PETE LAWRENCE

Jupiter presents a wealth of detail but tantalisingly this can be tricky to image because of the planet's fast spin rate. Jupiter has a diameter of 139,822km making it the largest planet in our Solar System. Spinning on its axis in less than 10 hours, its gaseous form bulges at the equator producing an oblate disc through the eyepiece. Fierce jet streams rage around the planet, the atmosphere appearing banded and turbulent.

The Earth's atmosphere blurs and distorts the disc of a planet. The best way to image one is by using a high frame rate camera: by capturing lots of sequential frames, some of the images will be less distorted than others. Using a registration-stacking application such as *RegiStax* or *AutoStakkert!*, it's then possible to capitalise on the better frames, extracting them from the pack, registering them together and averaging the result. Cameras with frame rates ranging up to several hundred frames-per-second (fps) are common these days.

Honing your planetary imaging skills on a fast-rotating planet like Jupiter can take lots of practice and matters are further complicated when the Galilean satellites become involved. Io, Europa, Ganymede and, to a lesser extent, Callisto, can all appear to interact with Jupiter's disc, passing across it as a transit and casting their shadows on its surface in what's known as a shadow transit.

The main issue with moon and moon shadow transits is that they take place at a different rate to the rotation of the planet below. Advanced techniques such as disc de-rotation, allow for extended capture times beyond which extensive motion blur would normally occur. They work by effectively rotating all of the frames back to a common time, undoing the rotation of the planet. When a moon transit becomes involved, de-rotation doesn't work as well because of the relative motion of the moon.

One way around this problem is to keep your captures short. This produces noisier end results but at least everything appears relatively sharp. Taking lots of short captures will allow you to produce a sequence of results which can be added together as an animation. The benefit of this technique is that it creates a dynamic record of Jupiter's rotation as well as the moon and shadow transit. It also helps disguise the additional noise in each capture result.

Our step-by-step guide opposite shows how to create a monochrome animation using a mono, high frame rate camera fitted with an infrared pass filter. A mono camera could be used with individual RGB filters but this would entail a lot of work and open the door to additional issues because of the relative motion of the moons and their shadows. One big advantage of using an infrared pass filter in conjunction with a mono-camera is that it can make moons such as Io and Europa clearer to see as they shine brighter in infrared than they do in visual wavelengths.

Alternatively, a one-shot, colour, high frame rate camera can be used, but with Jupiter now getting lower as seen from the UK, the best results require a more advanced approach using an optical device called an atmospheric dispersion corrector (ADC). This is used to counteract the effects of atmospheric dispersion that become more evident for objects lower in the sky.

However you do it, a successful animation of the Jovian system is a delight to watch as it really helps emphasise how the Galilean moons move in their orbit around their host planet.

THE BIG PICTURE

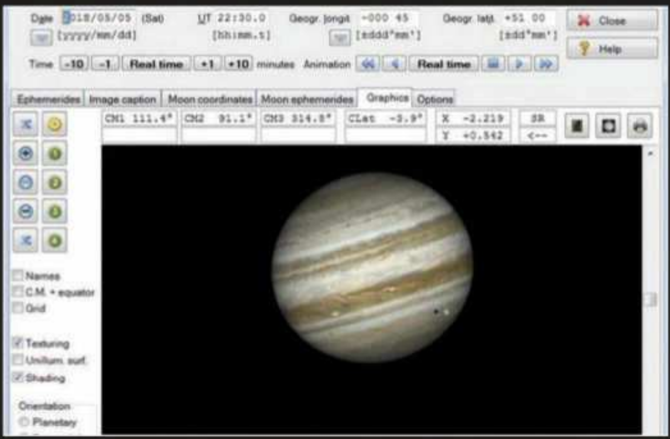
ANIMATION REVEALS MORE

Jupiter is a wonderful planet to image but if you take too long when collecting your images it's easy to introduce motion blur, taking the edge off any fine detail. This is especially true when attempting to image special events such as transits of the Galilean moons.

The problem here is that you have two rapid motions to deal with; the spin of the planet and the relative motion of the moons and their shadows. Short captures are the key but can produce noisy results. A good compromise is to create an animation. The movement you record can produce a fascinating result that brings home how three-dimensional the Jovian system really is.

✉ Send your images to:
hotshots@skyatnightmagazine.com

STEP BY STEP



STEP 1

Identify when a moon will next be in transit. We have mentioned a number of key events in our calendar on pages 50 & 51 with additional details on page 56. Alternatively, the freeware program *WinJUPOS* allows you to work out what events are coming up, giving you enough information to plan your observations.

STEP 2

Choose an image that clearly shows the planet's disc, moon and shadow. Too small a scale and the motion of the moon and its shadow will be difficult to show over smaller timescales. A focal length of at least 3m is recommended. A Barlow lens or Powermate are ideal ways of upping your telescope's effective focal length.

STEP 3

Set your equipment up. Telescopes need time to acclimatise to the outside temperature. For large instruments this may take several hours. Check collimation. Defocus on a medium-bright star and observe the diffraction pattern. If it's asymmetric, your collimation needs correcting. It's best to star-test at the focal length you intend to use.

STEP 4

Using a mono, high frame rate camera with an infrared pass filter will give the sharpest results. A sequence capture time of up to 90s for focal lengths up to 4m, and 60s for longer setups is recommended. Repeat captures sequentially for at least as long as it takes to show some movement of the moon and its shadow.

STEP 5

Process each capture with a registration-stacking application such as *RegiStax* or *AutoStakkert!*. Using *AutoStakkert!* as an example, it's possible to drag all of the capture files into the application, define the processing parameters for the first one and then batch process them all. If all goes well, the end result will be a set of relatively clear stills.

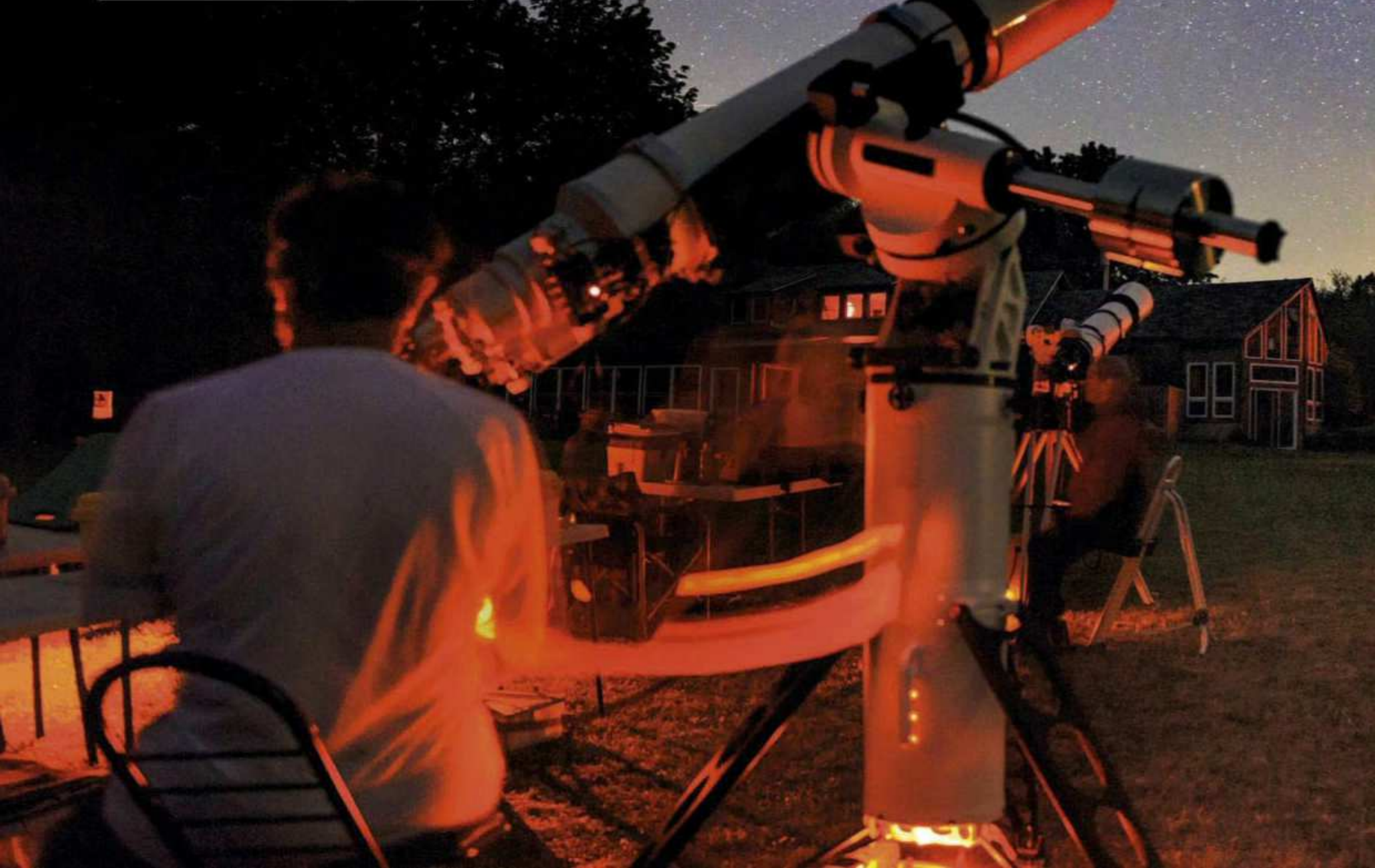
STEP 6

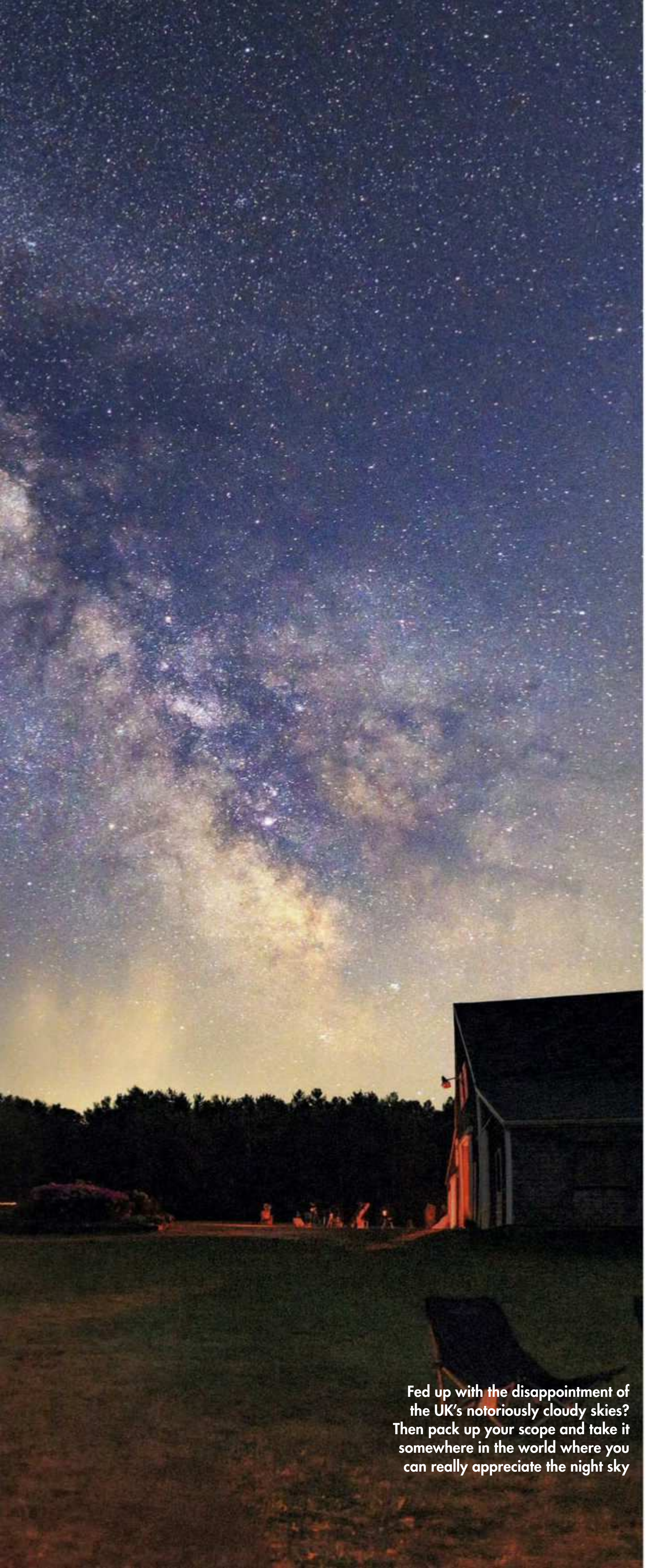
The simplest way to animate the images is to load them in sequence in a layer-based editor such as *Photoshop*. Align all planet discs to the lowest layer. Open the animation timeline control and create as many panes as there are layers, showing a separate layer for each pane. The option to 'Save for Web…' allows you save as an animated GIF.

Have scope, WILL TRAVEL

Astro tourism has exploded in recent years. Astronomer **Will Gater** goes globetrotting to find the best ways for the stargazer to travel

ABOUT THE WRITER
Will Gater is an astronomy journalist, author and presenter. Follow him on Twitter at @willgater or visit willgater.com





Fed up with the disappointment of the UK's notoriously cloudy skies? Then pack up your scope and take it somewhere in the world where you can really appreciate the night sky

BABAK TAFRESHI/SCIENCE PHOTO LIBRARY

The annals of science brim with tales of daring expeditions and arduous journeys undertaken by astronomers hoping to catch sight of eclipses, auroral displays and magnificent, starry night skies. But whereas a century or so ago, perhaps even less, it would have been only the privileged few who could embark on such exploits, nowadays astronomical adventures around the world are increasingly within the reach of more and more of us.

The snowballing popularity of 'astro tourism' – in the UK and abroad – has been striking in the last decade, as holiday companies, travel agencies and tourist organisations have all gradually realised the tremendous draw of trips with an astronomical theme. Today there are operators offering holidays to see specific celestial events, like meteor showers and total solar eclipses, while even big-name travel companies list Northern Lights breaks in their brochures. But it's not just with package tours that amateur astronomers are now globetrotting in search of celestial splendours.

Thanks to budget airlines and accommodation websites, many UK stargazers are now organising their own trips to dark-sky locations in Europe with better weather prospects than here at home, as well as more exotic destinations such as the Arctic with its 'bucket-list' spectacle, the Northern Lights. For example, the airline Norwegian offers direct flights from London to Tromsø in northern Norway while easyJet flies to Reykjavik in Iceland and the stargazing Mecca of Tenerife, in the Canary Islands.

Another thing that has made travelling for astro imaging and observing purposes much easier in recent years is the development of lightweight, portable tracking mounts and high-quality, compact refractors. Previously, if you weren't able to take a bulky tracking mount to your destination, you'd almost certainly be limited to taking relatively wide images with either a static photo tripod – using short exposures, fast camera lenses and high ISOs – or a basic motorised mount.

Kit the road, Jack

Modern portable tracking mounts, though, have advanced tremendously and now allow imagers to shoot at longer focal lengths or achieve much deeper wide-field images with regular camera lenses; some even have the ability to receive commands from an auto-guiding system. Such capabilities are especially useful for capturing the kind of targets that UK-based astrophotographers might seek through travel, such as an exceptionally dark sky, the ▸

Sites of celestial interest

There are hundreds of astro tourism destinations around the world. Here are the best known

Australia and New Zealand

Both Australia and New Zealand need no introduction as alluring holiday destinations with their beautiful coastlines and spectacular scenery. But for we astronomers they're also the perfect places from which to explore the magnificent southern hemisphere sky. Indeed, the most sparsely populated regions in both countries – such as the Australian Outback and the remote mountainous areas of New Zealand – are among the best locations in the world to stargaze, full stop.

La Palma and Tenerife

Sitting off the coast of northwest Africa, the spectacular volcanic islands of La Palma and Tenerife are synonymous in European astronomy circles with pristine dark skies. Both islands are home to professional observatories – the William Herschel Telescope, the Isaac Newton Telescope and the enormous Gran Telescopio Canarias being just a few of the world-famous research facilities that are sited on La Palma – that are occasionally open for daytime visits. (See page 72 for more.)

Northern Finland, Norway and Sweden

The Arctic landscapes of northern Finland, Norway and Sweden are stunning to behold, but it's the possibility of catching sight of the ethereal Northern Lights dancing across the skies that draws many UK astronomers to this beautiful region in winter. For example, there are frequent flights from London to Tromsø in northern Norway, and from there you can book guided night excursions away from the city in search of the aurora (which, sadly, can never be guaranteed to appear).

Chile

Chile, in South America, is another popular destination famous with astronomers for its clear, dark night skies. Many of the world's most powerful research telescopes are sited in remote regions of the country, including ESO's Very Large Telescope (VLT) array, which sits atop a mountain at the Paranal Observatory, and the Atacama Large Millimeter/Submillimeter Array (ALMA), which is located in the Atacama Desert, far up in the north of Chile, close to the border with Bolivia.

The United States

The southwestern US states of Arizona and New Mexico, along with California on the west coast, boast some breathtaking sights and scenery, from the majestic Grand Canyon to iconic locations, such as Yosemite National Park and Joshua Tree National Park. But these states are also where you'll find famously dark night skies too. In fact, the region includes a high density of International Dark Sky Places recognised by the International Dark-Sky Association.

Greece

With azure waters lapping its beaches, abundant sunshine, stunning architecture, delicious cuisine and curious alcoholic beverages, Greece offers some of the most enticing places to holiday in all of Europe. If you can get away from the lights of the towns and cities, the country – and especially some of the Greek islands – can also be a great place to stargaze. The island of Crete, for example, is home to a professional observatory that occasionally runs public open days.

Namibia

There are few places that spark the imagination and excitement of astronomers and astrophotographers around the world more than Namibia in southwest Africa. Just look at the pictures taken by astro imagers there and you'll immediately understand why; not only does its location provide a perfect view of the southern night sky, but the country also possesses extraordinarily dark night skies, especially at sites near the beautiful Namib Desert.

Iceland

Being only a few hours away by air, Iceland, in the North Atlantic, is a favourite destination for UK and European stargazers hoping for a sighting of the Northern Lights. Iceland sits in the region known as the 'auroral zone', where displays of aurora can frequently be seen, which improves your odds of witnessing a display. If the skies are cloudy when you're there you'll still be able to enjoy exploring the island's spectacular volcanic landscape, enormous glaciers and towering waterfalls.

▲ Northern Norway and Iceland are popular destinations for astro tourists who want breathtaking views of the Northern Lights

▼ Advances in technology mean that amateur astronomers can now pack a lot of powerful kit into just a carry-on luggage bag

▸ southern hemisphere Milky Way or iconic objects like the Magellanic Clouds (see page 70).

Today, providing your equipment is all suitably protected and padded, it's possible to fit a very capable portable mount – such as Sky-Watcher's Star Adventurer or the Vixen Polarie – as well as a small scope and a DSLR camera into a typical, carry-on luggage bag. This has particularly opened up deep-sky DSLR astrophotography when you're travelling abroad.

If you're thinking of going on an astronomy holiday – either one arranged by yourself or with a professional tour company – it's worth preparing carefully how you're going to get your kit to your destination. Of course, you'll want to check that your most sensitive equipment is secure and safely protected; for example, keep any scopes, lenses and cameras you take on flights abroad in a specially padded, carry-on-sized rucksack, so that you can keep an eye on them and put the bag gently into the overhead lockers yourself. If you do this, it's worth double-checking the size and weight restrictions for your carry-on luggage for all flights on your trip, especially regional connecting flights, as sometimes these can vary across one journey and the last thing you want is to find your carry-on bag full of delicate kit has to go in the hold.

If you're going by air to your destination another thing to be aware of, and abide by, are the restrictions and regulations on taking lithium-ion and lithium metal batteries on aircraft. These are very often found in the kind of equipment that travelling astronomers carry, including DSLR cameras and power-packs used for powering motorised mounts or charging mobile phones. It's therefore highly recommended that, a good while prior to travelling, you check and familiarise yourself with the rules regarding these batteries for the airline that you are going to be flying with.

Consider clothing and comfort

Preparing for stargazing or imaging abroad isn't just about dealing with kit logistics, however; there are many other elements that you need to consider for a successful, safe and enjoyable trip. For example, if you're heading to the Arctic to see the Northern Lights you'll obviously be taking a load of warm clothes. But in the daytime it can be really quite bright and sunny, and the air can be very dry too, so you might want to pack sun cream, sunglasses and a decent lip balm.

When chasing total solar eclipses, it's often easy to focus on bringing the right astronomical kit and forget that – if your trip is successful – eclipse day itself will mean sitting in the sun for several hours. So think about what you'll need to keep shaded and cool, in terms of clothing and hydration, and how to make yourself comfortable during that time, by packing a cushion or rug to sit on, for example. And for general stargazing remember that even in warm ▸

Astronomical attractions

There are many celestial sights that astronomers are willing to travel to see

Heart of the Milky Way

The beautiful region of the Milky Way consisting of the star fields, bright clusters and nebulae around the spout of the Teapot asterism is low in UK skies in Sagittarius in the summer months. However, you don't have to travel far south to get a better view of this patch of sky; even sites in southern Europe will elevate it enough above the murk of the horizon to make observation and photography much easier.

The Northern Lights

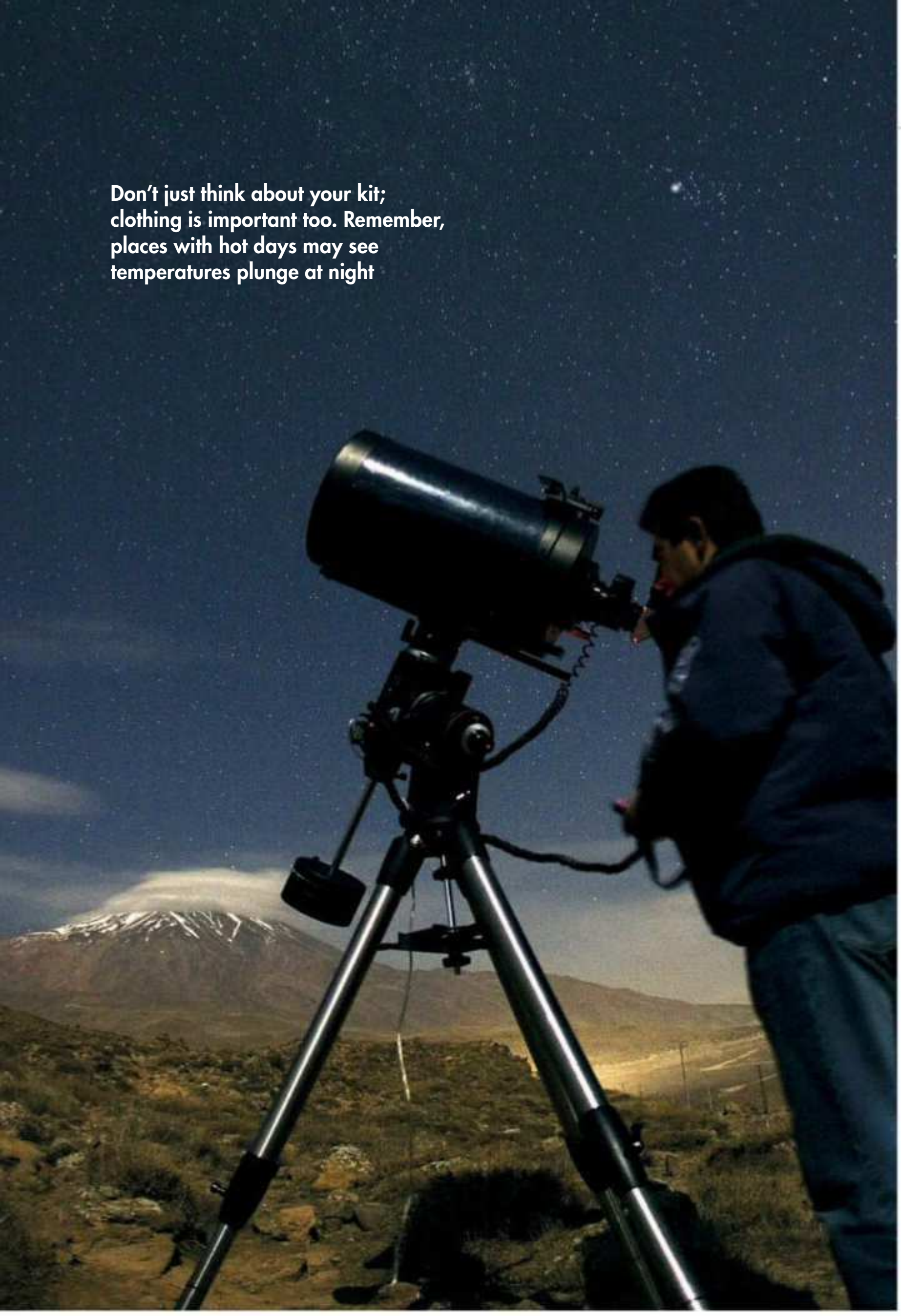
When Earth's magnetosphere is energised, charged particles can be fired along magnetic field lines into our atmosphere generating shimmering curtains of light – the aurora. The region where the energising is thought to occur connects with the magnetic field lines emanating from the polar regions of Earth. This is why places like Iceland, and the northern parts of Norway, Sweden, Finland and North America are great destinations for hunting the Northern Lights.

Magellanic Clouds and southern Milky Way

The southern night sky is perhaps most famous for two things. First, there's the bright band of the southern Milky Way which arcs high overhead at certain times of year, bursting with bright nebulae and dazzling stars. Second, there's a pair of objects known as the 'Large' and 'Small' Magellanic Clouds. These are two irregular galaxies nearby to the Milky Way that appear like bright smudges of light hanging against the sparkling sky.

Total solar eclipses

A total solar eclipse – where the Moon fully obscures the Sun's disc revealing the solar corona – is perhaps the quintessential bucket-list celestial sight. There are numerous companies all over the world who offer tours and holidays to see these awe-inspiring events, which are only visible from narrow strips of the Earth's surface, which are different with each eclipse. The next total solar eclipse will be visible from parts of Chile and Argentina in 2019.



Don't just think about your kit; clothing is important too. Remember, places with hot days may see temperatures plunge at night

▼ You'll regret leaving behind easily forgotten things such as spare batteries, adaptors, lip balm and sun cream

> "Before you go, researching the geography, climate and local weather for the place you're visiting is good practice"

▸ climate temperatures can sometimes drop dramatically at night under clear skies, so prepare for this if necessary.

Before you go, researching the geography, climate and local weather patterns for the place you're visiting is good practice for any astronomy holiday. Not only can it uncover observing sites with better clear-skies potential but it can also inform your choice of when to travel more broadly, especially when cross-referenced with online information about the times of local astronomical twilight, light pollution maps and Moon phases.

Getting familiar with the night sky over your destination before your trip can also help you hit the ground running when you get there. Planetarium software (like the free Stellarium) are ideal for this as you can enter your holiday location and travel date, and see what's up and where. This element of astro tourism is easily overlooked, but is especially advisable if you're travelling to a foreign dark-sky site for the first time – where the sheer number of stars can be overwhelming – or a destination where the night sky is very different from your home location, such as southern-hemisphere sites for UK-based astronomers.

Make sure you have the power

For travelling astrophotographers there are, naturally, lots of other little practical things to remember when imaging overseas. For example, ensuring you have the necessary travel adaptors or convertors to power your equipment or charge batteries; taking spare camera batteries with you; and – if you're going somewhere cold – keeping them protected from icy temperatures, which can drain them quickly.

For imagers embarking on their first astro vacation to the southern hemisphere it also pays to familiarise yourself with how to polar align an equatorial mount under the southern skies. You need to be aware that the process of locating the south celestial pole is totally different from finding the north celestial pole in the UK.

However, and wherever, you decide to explore the cosmos – be it in the UK, Europe or even further afield – with the tourist industry taking ever more advantage of the attraction of astronomy and the night sky for global travellers, you can guarantee that there's a destination out there somewhere that will suit your stargazing desires. Ⓢ

WILL GATER X 3, ISTOCK X 2, BABAK TAFRESHI/SCIENCE PHOTO LIBRARY

An impressive panorama of star trails over Teide volcano in Teide National Park on Tenerife

THE CANARIES

Islands of astronomy

The pitch-black skies of the Canary Islands offer some of the best views of the cosmos available on Earth, and the Spanish archipelago is opening its arms to astro tourists, says Inka Piegsa

Thanks to their warm climate, the Canary Islands are best known as a year-round holiday destination. Yet the group of seven islands, located in the Atlantic Ocean off the northwest coast of Africa, offers a less well known but equally tempting attraction: some of the darkest, clearest night skies in the world.

This natural phenomenon has drawn professional astronomers to the Canary Islands to observe the stars in conditions not found anywhere else. Observatories and specialised telescopes have been installed on the high peaks of the islands of La Palma, Tenerife and La Gomera.

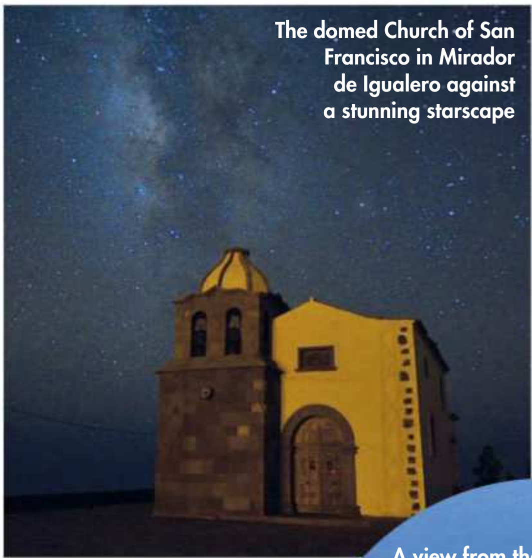
But it's not only professional astronomers who come to the Canaries. Recently a new form of leisure travel – astro tourism – has taken hold, and now amateur astronomers are travelling to the Canaries in ever greater numbers. Events, facilities and tours have sprung up to cater for their needs. So, if you're tempted to take advantage of the Islands' dark skies, here's a guide to the best places to go to marvel at the overhead views…

ABOUT THE WRITER

Travel writer Inka Piegsa-Quischotte's created and writes the blog www.glamourgrannytravels.com.

La Gomera

Size isn't everything. La Gomera may be one of the smallest and lesser-known of the Canary Islands but it offers a wider variety of views for astronomers



The domed Church of San Francisco in Mirador de Igualero against a stunning starscape

La Gomera may be the second smallest of the Canary Islands, but it offers a greater variety of locations from which to observe than either of the archipelago's other main astronomy-friendly destinations, La Palma and Tenerife. You can even follow a stargazing route that brings you to the best viewpoints on this volcanic island.

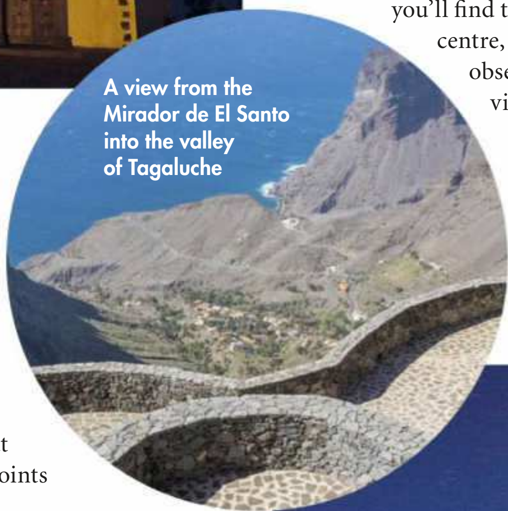
The route begins at the Mirador César Manrique viewpoint, which is easy to find on the road from Valle Gran Rey on the island's west coast. When we visited in late February, we were treated to crisp views of Orion's Belt and the Orion Nebula.

From there you can work your way around to Mirador de El Santo near the tiny village of Arure where we were treated to some impressive views of the Milky Way and enjoyed tracing the main stars in the constellation of Gemini from its fainter members.

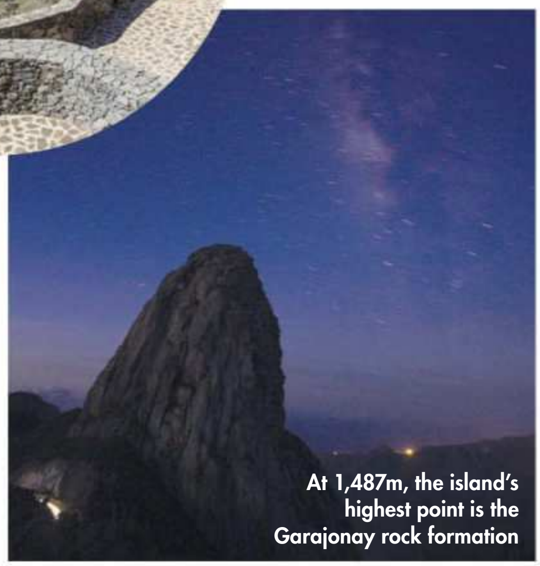
Your next stop should be Mirador de Alojera. Our view from here was dominated by Ursa Major and Minor, aka the Great and Little Bears. Tracing a straight line north from Ursa Major's pointer stars, we found Polaris sparkling in unparalleled splendour at the end of Ursa Minor's tail.

Venture to the heart of the island and you'll reach the top of the Garajonay rock formation, which lends its name to the National Park that surrounds it. The park is criss-crossed with hiking paths that allow access to the best stargazing viewpoints. At 1,487m, the summit forms another natural platform from which we took in the Milky Way and the constellations of Sagittarius and Scorpius, where Antares, a red supergiant star 400 times bigger than our Sun, shone brightly and the globular cluster M4 revealed itself in binoculars.

At the edge of the Garajonay National Park you'll find the Las Nieves recreation centre, another good spot for observing, where we enjoyed views of Auriga and Gemini. It's also a place with excellent parking facilities and refreshments, so serves as a natural rest stop on your 20km drive back to the island's capital San Sebastián. ▸



A view from the Mirador de El Santo into the valley of Tagaluche



At 1,487m, the island's highest point is the Garajonay rock formation

WESTEND61 GMBH/ALAMY STOCK PHOTO, JUAN JOSÉ BARRERA, ISTOCK, BLICKWINKEL/ALAMY STOCK PHOTO

▲ By day from Roque de los Muchachos you can see Tenerife, El Hierro and La Gomera; by night you can see the stars more clearly than just about anywhere else on Earth

La Palma

The volcanic holiday island can also boast an astronomical world first and an observational record-breaker

La Palma, the most northwesterly of the Canary Islands, has dark and clear skies thanks to the high altitude of much of its land area and a favourable inversion layer, which traps clouds, humidity and dust at relatively low altitudes. Indeed, an observatory containing the world's largest optical infrared telescope, run by the Instituto de Astrofísica de Canarias (IAC), stands at the top of the Moon-like mountain area known as Roque de los Muchachos.

Despite its altitude of 2,396m – the highest point on the island – the observatory is easily reached by car from the capital, Santa Cruz de La Palma, and provided you book a day in advance, guided tours are available to explain the views. Remember to bring warm clothes, snacks and drinks: there's no catering at the observatory.

Protecting the dark skies over all of the Canary Islands is the absolute priority. The Law for the Astronomical Quality of IAC Observatories is strictly enforced and the result is that the IAC/La Palma was declared the world's first Starlight Reserve in 2007.

There are two more outstanding points from which to observe the stars in La Palma. The first is San Borondón, a natural terrace jutting out over the Atlantic Ocean, where from mid-autumn onwards you can see the North Star and the constellation of Cassiopeia with remarkable clarity.

The second is Llano del Jable, a viewpoint that's another Starlight Reserve. It sits at an altitude of 1,200m on top of a dormant volcano in the El Paso mountain range, and forms a natural balcony from which the nearest galaxy to Earth, Andromeda, is easily visible.

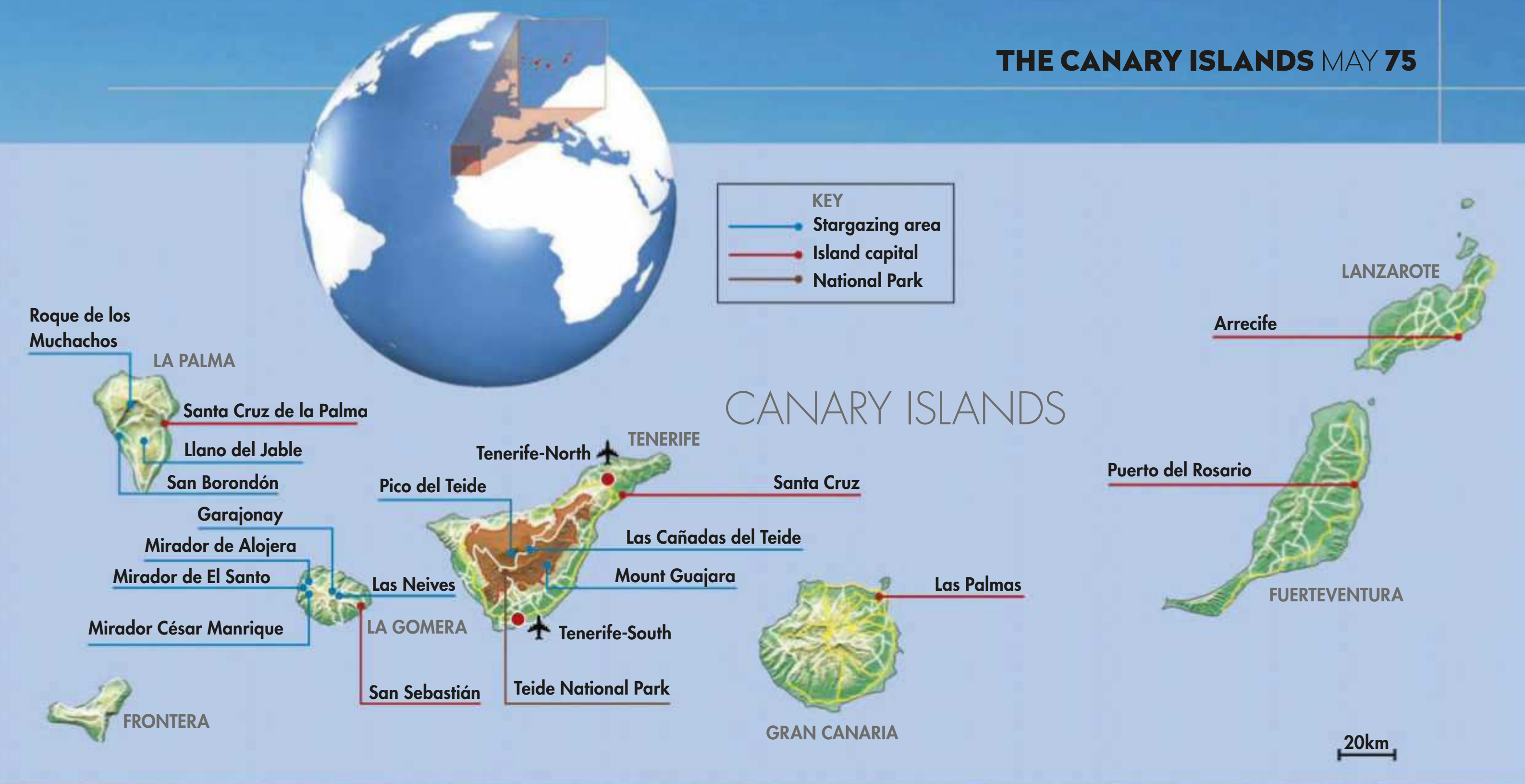
When we visited on a moonless night, we were able to detect some nice detail in the Great Square of Pegasus with the naked eye, but binoculars brought out more. There are no guided tours here, but information panels at the site are of great help.

All three of the observation points on La Palma form part of the EU Sky Route (**www.euskyroute.eu**), created for the great number of astronomy enthusiasts who visit the islands. ▸

▼ From Llano del Jable it's sometimes possible to make out the Andromeda Galaxy with just the naked eye

The Observatorio del Roque de los Muchachos (ORM) has an extensive array of telescopes

AUTHOR ATTILA MUZLINGER/ROMANIA/EXPEDITION SARM AND ASTRO TRAVELS/LA PALMA 2016 X 2, MAURITIUS IMAGES GMBH/ALAMY STOCK PHOTO, MAPS BY PAUL WOOTTON, ISTOCK X 2, PARADOR DE LA PALMA, JAN WLODARCZYK/ALAMY STOCK PHOTO



GETTING THERE

You'll likely fly into Tenerife then hop on to other destinations by air or boat. There's accommodation for all budgets

Flights

Tenerife has two airports, Tenerife-North and Tenerife-South. Only Tenerife-South has direct flights from UK airports (Luton, Stansted, Gatwick, Bristol and Manchester). February and September are the cheapest months to fly with tickets around £100.

La Palma is reached by air from Tenerife-North or by ferry from Tenerife-South or La Gomera.

La Gomera has a tiny national airport. It's best reached by ferry from Tenerife-South, or if you happen to arrive in Tenerife-North you can fly.

Accommodation

On **Tenerife** there is a choice of over 2,100 places to stay, from the posh Ritz Carlton (£1,325/ 1,500 ppn) to B&Bs (£45/ 50ppn). Package deals are also available from UK travel agents.

La Palma has plenty of accommodation, from the five-star Parador de la Palma (£133/ 150) to apartments and hostels (£34/ 38).

La Gomera has around 200 hotels with an average price of £75/ 90 at the top end. (All prices depend, of course, on season.)

Getting around

Public transport Tenerife: www.tenerife-information-centre.com/public-transport.html

Bus services on La Palma: www.transporteslapalma.com

Public transport for La Gomera: www.gomera.info/bus.htm

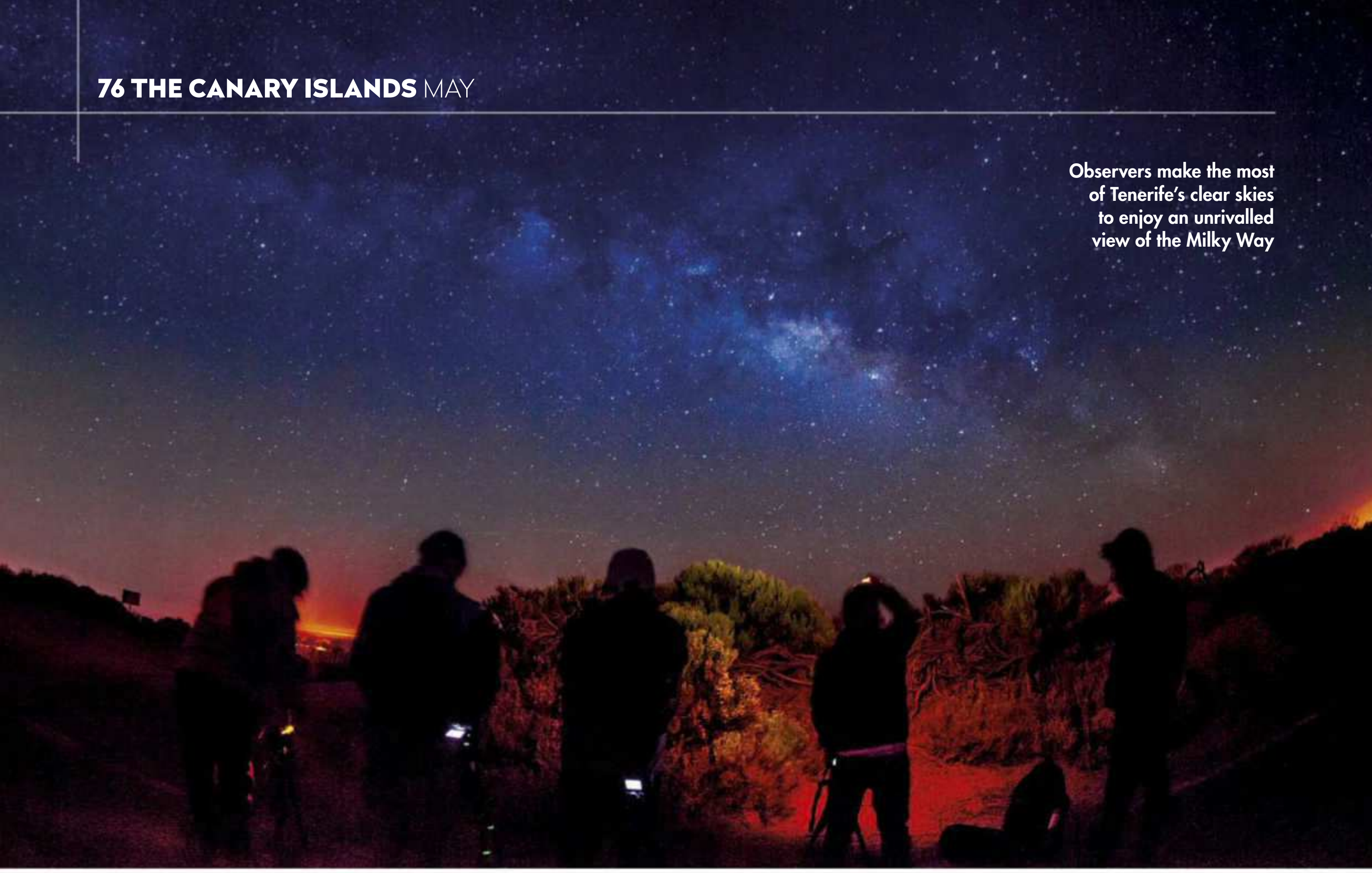
Island-hopping: www.hellocanaryislands.com/travelling-between-islands

All major car hire companies are represented on the islands.

▲ You can get direct flights from various UK airports to Tenerife-South airport

▲ The Parador de la Palma hotel is situated near Palma's capital Santa Cruz de la Palma

▲ You don't need to tip for taxi rides but it's polite to round up fares to the nearest Euro



Observers make the most of Tenerife's clear skies to enjoy an unrivalled view of the Milky Way

Tenerife

Use the telescopes at the island's observatory, or trek up a mountain for striking views of Pegasus and Cassiopeia

Stargazing on Tenerife, the largest of the Canary Islands, can be quite an adventure. The Teide National Park, a World Heritage Site, sits in the middle of the island, with the world's third largest volcano, Pico del Teide at its centre.

Las Cañadas del Teide, at close to 3,000m high, is the prime night sky viewing point on Tenerife and another of the Canary Islands' three Starlight Reserves. Professional astronomers use state-of-the-art telescopes at the huge observatory on top of nearby Mount Izaña, but astro tourists can also observe through them by taking one of the observatory's tours (the longest of which lasts eight-and-a-half hours and well into the night).

From Las Cañadas you'll have unobstructed views of the night sky. If you visit in August, it's a great place to spot Perseid meteors and bright star Vega.

Until recently, it's only been possible to reach Mount Teide after a two-hour hike along a winding path up the volcanic mountainside. Hiking remains the most exciting way to access the natural platform at the top, but there's now also the 'Sunset and Stars on Teide' guided tour that makes use of a cable car at sunset (see **volcanoteide.com** for details).

The highest viewing point for stargazing on Tenerife is found on Mount Guajara, also located within the Teide National Park. It's easy to reach the bottom by car, then it's several hours hiking to the top. During our ascent we had great views of Cassiopeia and Pegasus, and were greeted with the magic of the changing colours of dawn as we got to the summit. Halfway up there's a cabin where you can sleep and rest but there's no catering, so you need to take hiking gear, warm clothes, snacks and drinks with you. S

▲ Mount Guajara, an extinct volcano, offers Tenerife's highest viewing point

Observatorio del Teide with the peak of Mount Teide in the background

SKILLS

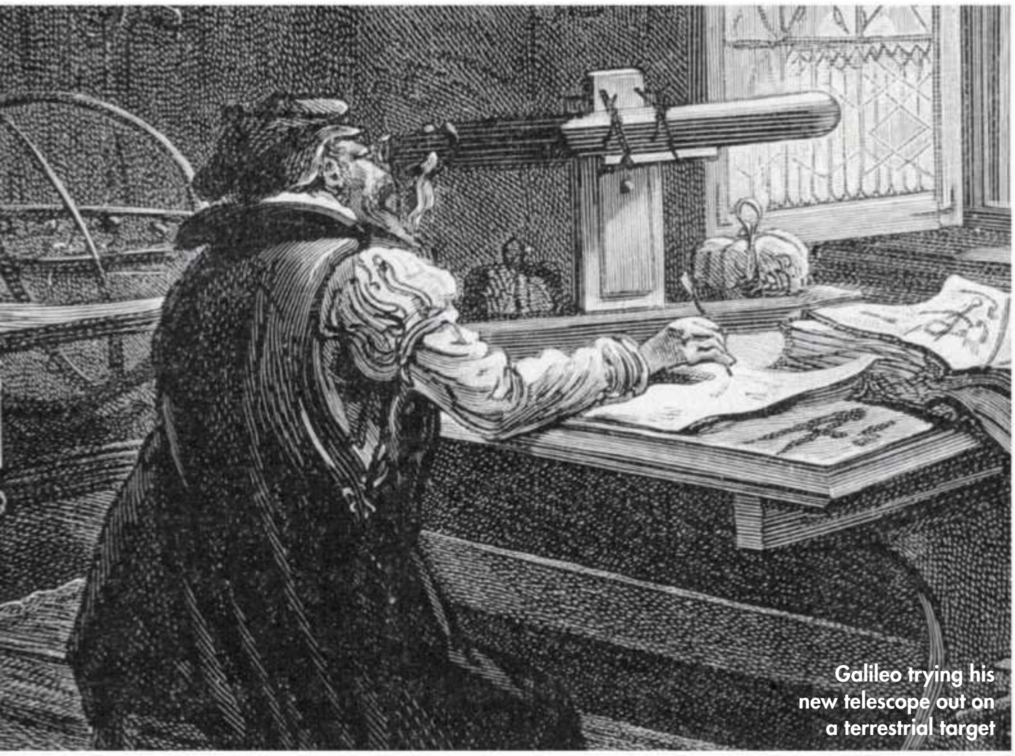
Brush up on your astronomy prowess with our team of experts

The Guide

With
Brian Jones

The discovery of the Galilean moons

Galileo gets the credit, but did he actually see Jupiter's four largest moons first?



Galileo trying his new telescope out on a terrestrial target

On the title page of Galileo's *Sidereus Nuncius* (*Sidereal Messenger*) – the first astronomical work based on telescope observations when it was published in 1610 – the author says that the book introduces the reader to "great and surpassingly wondrous sights… observed by Galileo Galilei, Florentine patrician and public mathematician at the University of Padua… in four planets revolving with remarkable speed at differing distances and periods around the star Jupiter. They have been known to no one up to this day, and the author was the first to discover them. He has decided to call them the Medicean planets."

The initial naming of the moons as the Medicean planets was to acknowledge the patronage he received from Grand Duke Cosimo II de' Medici of Tuscany (1590–1621), whom Galileo had served as mathematics tutor in 1605. Galileo's first idea was to name the newly discovered moons the Cosmica Sidera (Cosmian Stars) solely in honour of his patron, but ultimately chose a name that honoured all four surviving Medici brothers: Cosimo, Francesco, Carlo and Lorenzo.

Galileo also recognised that the four objects he had observed through his telescope were the first ever seen to orbit another planet, and the importance of his discovery was not lost on him. But though he may have been the first to name them, Galileo's claim to having been the first to see them has come under some doubt.

Possible earlier sightings

It has been suggested that the Chinese astronomer Gan De, who carried out some of the earliest known systematic observations of the planets in the 4th century BC, may have seen Ganymede. It was while he was studying Jupiter during the summer of 365 BC that Gan De recorded what he described as a 'small reddish star' next to the planet. The Chinese astronomy historian Xi Zezong (1927-2008) suggested this may have been an early sighting of Ganymede. It is theoretically possible to see the Galilean moons with the naked eye, but it requires near perfect conditions and incredible eyesight.

▲ Through Galileo's scope the moons were merely tiny points of light next to Jupiter

In 1614, around four years after *Sidereus Nuncius* was published, German astronomer Simon Marius (1753-1625) published his work


SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, suspiciendaque proponens
vnicuique, præsertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnasij Publico Mathematico
PERSPICILLI
Nuper à se reperti beneficio sunt obseruata in LVNÆ FACIE, FIXIS INNVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprime verò in
QVATVOR PLANETIS
Circa IOVIS Stellam disparibus interuallis, atque periodis, celeritate mirabili circumuolutis; quos, nemini in hanc vsque diem cognitos, nouissimè Author depræhendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.
VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permissu, & Priuilegio.
M VIIII

RECENS HABITAE. 23
dentalis proxima min. 2. ab hac vero elongabatur oc-
Ori. Occ.
cidentalior altera min: 10. erant præcisè in eadem recta, & magnitudinis æqualis.
Die quarta hora secunda circa Iouem quatuor stabant Stellæ, orientales duæ, ac duæ occidentales in
Ori. Occ.
eadem ad vnguem recta linea dispositæ, vt in proxima figura. Orientalior distabat à sequenti min. 3. hæc verò à Ioue aberat min. 0. sec. 40. Iuppiter à proxima occidentali min. 4. hæc ab occidentaliori min. 6. magnitudine erant ferè æquales, proximior Ioui reliquis paulo minor apparebat. Hora autem septima orientales Stellæ distabant tantum min. 0. sec. 30. Iuppiter
Ori. Occ.
ab orientali viciniori aberat min. 2. ab occidentali verò sequente min. 4. hæc verò ab occidentaliori distabat min. 3. erantque æquales omnes, & in eadem recta secundum Eclypticam extensa.
Die quinta Cœlum fuit nubilosum.
Die sexta duæ solummodo apparuerunt Stellæ me-
Ori. Occ.
dium

▲ **Galileo's *Sidereus Nuncius* (1610) was the first published work to record the "Medicean Stars" (as he toadyingly called them), which were first mentioned on the page pictured on the right**

Mundus Iovialis (1614) in which he described the planet Jupiter and its moons. He laid claim to having discovered them in December 1609. This would mean that Marius had spotted the Jovian moons some time before Galileo who, according to *Sidereus Nuncius*, had first seen them on 7 January 1610.

However, what *is* certain is that Galileo was the first to publish what he saw. It was on that date that Galileo turned his telescope towards Jupiter and noticed what he described as "three little stars… positioned near (Jupiter) – small but yet very bright" and noting the presence of a fourth 'little star' a few days later. Although his first thoughts were that these were 'fixed stars', Galileo was sufficiently intrigued by the fact they were "arranged exactly along a straight line and parallel to the ecliptic" to continue his observations, which ultimately revealed their true nature.

After announcing the moons in *Sidereus Nuncius*, independent verification and sightings of the newly discovered Jovian moons came from a number of sources. These included such noteworthy observers as Johannes Kepler in Prague, English astronomer Thomas Harriot and French astronomer Joseph Gaultier de La Vallette.

Regardless of who saw them first the mythological names by which these satellites are known today are those given them by Marius (inspired by a suggestion from Johannes Kepler). In 1614, he wrote in *Mundus Iovialis*, "Io, Europa, the boy Ganymede and Callisto greatly pleased lustful Jupiter." However, the names didn't gain favour until the early 20th century, mainly because Galileo refused to use them. In the meantime, they were generally referred to as Jupiter I, II, III and IV according to their closeness to Jupiter.

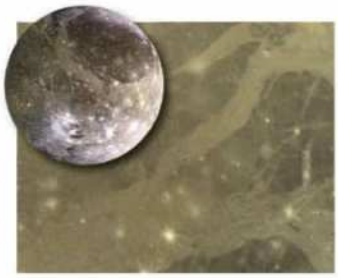
It would be another few centuries until Jupiter's next moon, Amalthea, was discovered by American astronomer Edward Emerson Barnard using the 36-inch Great Lick Refractor at Lick Observatory on 9 September 1892. Amalthea holds the distinction of being the last planetary satellite to be discovered by direct visual observation. The sixth Jovian moon, Himalia, was revealed on 3 December 1904 using astrophotography, as have all of its many subsequently discovered moons. Since then, the number of confirmed moons orbiting Jupiter has increased greatly, and at the time of writing the number of known satellites stands at well over 60.

BRIAN JONES has written 17 books on astronomy for children and adults

Galilean moons Jupiter's four biggest moons are very different worlds

Io
Diameter 3,660km
Mass 0.015 Earth masses
Orbital distance 421,700km
In brief Io, the closest moon to Jupiter, has over 400 volcanoes across its surface. The gas giant's constant gravitational tugging keeps its interior molten.

Europa
Diameter 3,122km
Mass 0.008 Earth masses
Orbital distance 670,900km
In brief The smallest of the moons, Europa is covered in a thick layer of ice. Beneath this is a liquid water ocean that could be hospitable to life.



Ganymede
Diameter 5,268km
Mass 0.025 Earth masses
Orbital distance 1,070,400km
In brief The largest moon in the Solar System. It is thought to have a large rocky core covered with layers of ice and water which show signs of tectonic activity.

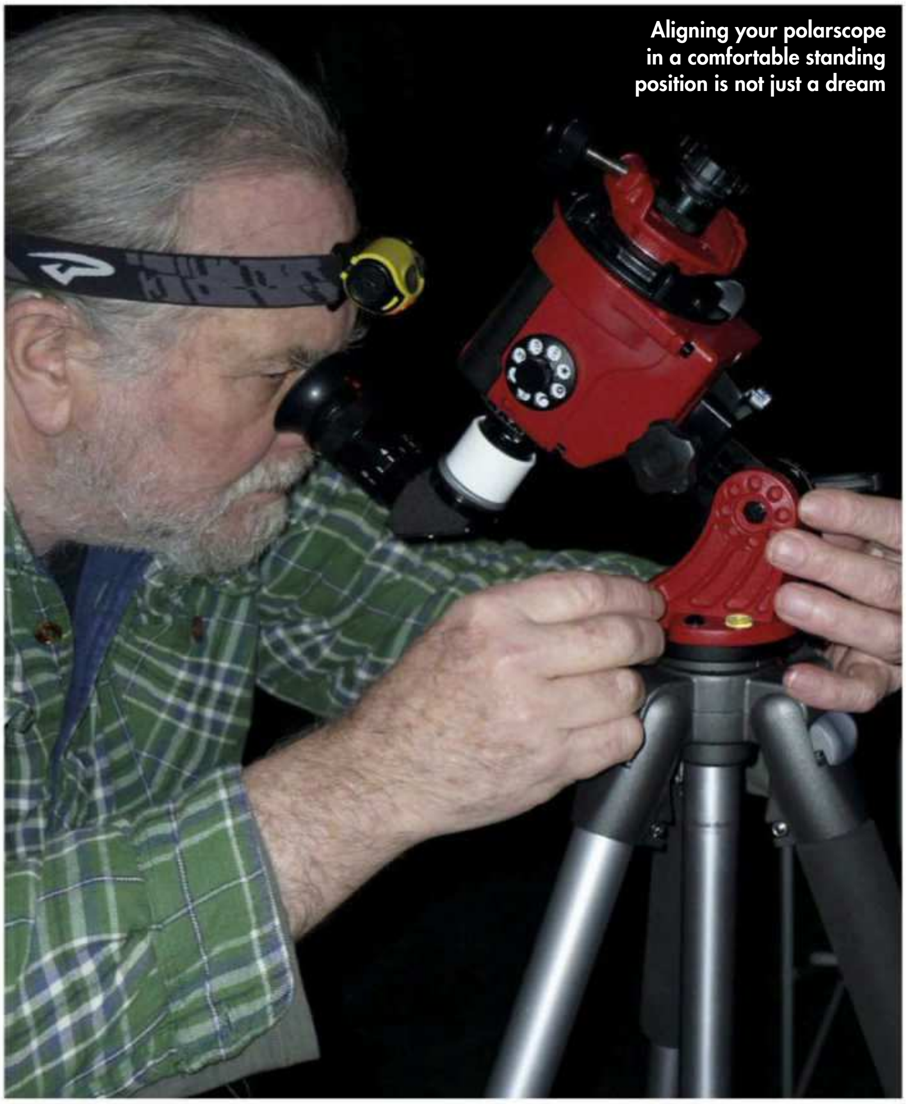
Callisto
Diameter 4,821km
Mass 0.018 Earth masses
Orbital distance 1,882,700km
In brief The least active of the Galilean moons. Its ancient surface is almost completely covered in craters, so every new crater erases an older one.

With **Stephen Tonkin**

How to...

Build a right-angled polarscope adaptor

The simple DIY solution to taking the back strain out of the aligning process



Aligning your polarscope in a comfortable standing position is not just a dream

Do you enjoy getting damp knees, back-ache and a stiff neck as you struggle to use the eyepiece of your polarscope when you're trying to get your mount decently aligned? No? Neither do we.

There's not much point in an equatorial mount unless it's properly aligned but, marvellous as polar alignment scopes are, they have never been designed for comfort. Being uncomfortable isn't just unpleasant, it's also a disincentive, so you have to welcome any way of making the polar alignment process less of a back strain.

There are several software solutions, and you can even fit a cheap webcam to the polarscope so that you can view the alignment reticule on a screen. But these all add complexity to what, in a perfect world, should be a quick and simple process. The ideal solution for frequent polar alignment, especially when you're using a portable tracking mount in the field, needs to be one that doesn't require computers, electrical power or the skills of a contortionist.

The discomfort arises from two factors. Firstly, the polarscope, from UK latitudes, must be aimed at an elevation of 51° or higher. Your neck has not evolved to the point where you can comfortably look up at that angle except for short periods. Secondly, the polarscope eyepiece may be at chest height or lower. Forget about sitting: putting a seat in the required position results in a territorial dispute between the chair's legs, the tripod's legs and your legs. Getting your eye in the right position requires either kneeling or bending your back at the sort of unnatural angle that contravenes every chiropractor's idea of good posture. Both bending and ▸

ALL PICTURES: STEPHEN TONKIN

TOOLS AND MATERIALS

TOOLS
Callipers for measuring the finder's bayonet connector and scissors for cutting out the template. If you're using a soft plastic tube like a film can, you will need a craft knife. If you're using a hard plastic tube then a multi-tool with a small milling bit is ideal.

MATERIALS
A right-angled finder for an SLR camera. A tube, closed at one end, that's a loose fit on the polarscope eyepiece – a 35mm film can or 36mm pipe end-cap may fit. The 'loop' side of some self-adhesive hook-and-loop fastener tape.

SUNDRIES
Card, electrician's insulating tape, permanent marker, bench vice, safety goggles.

▸ kneeling increase the temptation to use the tripod as a support when you get to your feet, affording you every opportunity to knock the system out of alignment again. Plus, kneeling leads to wet knees.

The simplest solution is the one that we all use at the eyepiece of a refracting telescope: a star diagonal. Fortunately, the essential components are readily available at reasonable cost. The heart of this project is a right-angled finder attachment designed for use with the viewfinder of a DSLR camera.

There are several different types available and your choice should be dictated by the ease with which it can be fixed to the tube that will go over the polarscope's eyepiece. The Pentacon-branded one is particularly suitable because it has a bayonet-type connector that merely requires you to cut a shaped aperture in the connecting tube and not have to bother about drilling screw-holes or making complicated mating pieces.

Finding a cheap finder

Many second-hand finders have lost the attachment that slips over the camera's viewfinder surround, and so are available very cheaply. A right-angled finder also gives a correct image, so you don't have to allow for a reversed polarscope reticule. If your polarscope has a 30mm diameter eyepiece, such as the common Sky-Watcher or Vixen ones, the tube can be fashioned from either a 35mm film can or a 36mm ABS waste-pipe stop. Alternatively, it could be a useful 3D-printing project.

You need to use loop tape to make the tube fit snugly to the eyepiece. Trial-and-improvement is the best method for determining the appropriate amount to use. It needs to be enough to prevent the finder from falling off, rotating or tilting, but not so much as to make it difficult to get it on or off.

To use your new creation, first roughly align your mount. A bright penlight torch shone up the polarscope eyepiece, producing a collimated beam that you can direct at Polaris, is useful for this (as long as doing so won't inconvenience fellow observers). If necessary, set the polarscope's time and date, put the finder on the polarscope and place Polaris in the appropriate part of the reticule. Then take it off and enjoy a comfortable observing or imaging session with dry knees and an ache-free back and neck. Ⓢ

STEPHEN TONKIN is author of *Binocular Astronomy* and editor of *binocularsky.com*

ALL PICTURES: STEPHEN TONKIN

STEP BY STEP

STEP 1

A card template is useful to test that you've measured correctly. Draw around the tube to get a circle, then carefully measure the bayonet connector of the right-angled finder and draw its shape in the centre of the circle you've drawn.

STEP 2

Cut out the template and make sure it fits the finder. If it does then – ensuring the template is properly positioned on the tube end – draw around the aperture with a permanent fine-point pen (non-permanent marks may not survive the next step).

STEP 3

Carefully cut out the aperture in the end of the tube, ensuring you follow any safety precautions recommended by the tool's manufacturer. Remember – because you drew *inside* the template aperture, you will need to cut *outside* of the marked lines.

STEP 4

Use a fine file to smooth any rough edges and 'tweak' the shape of the aperture. Experiment to determine the appropriate amount of loop tape to give a snug fit to the eyepiece of the polarscope. Film canisters usually need less tape than end-caps do.

STEP 5

If you used a film can, cut it to 25mm long and reinforce the cut edge with insulating tape. Mate the tube to the finder and rotate it through 90°. Tighten the locking ring on the finder until the tube will no longer rotate.

STEP 6

Fit the finder to the polarscope and ensure that the reticule is visible in the centre of the field of view. If it isn't, this is usually because it is tilting slightly, so you will need to adjust the amount of loop tape inside the tube.

Remote Hosting and Astro Breaks at probably the worlds best facility, E-Eye, Fregenal de la Sierra, Spain
Up to 270 clear nights a year from only 381 Euro per month for your own 3m x 3m observatory!
Why wait for the clouds to clear!
UK Exclusive Partner
Specialised secondary mirror focusing and correctors for Celestron SCT and EDGE telescopes.
ASA
Partner your binoculars or telescope with the Astrograph / APM Encoder Fork Mount and Astro Devices Nexus
Specialist observatory automation and weather monitoring equipment.
We also offer bespoke design and installation services for your observatory or remote hosted system
The worlds finest mounts and reflectors for perfect imaging performance by Astro Systeme Austria
ON DEMONSTRATION under Spanish skies!
UK Exclusive Partner
Astro Devices Digital Setting Circles Convert your manual mount to 'Push To' simplicity
UK Distributor
TecnoSky
A excellent range of Mounts, Accessories, Apochromat and Achromat Telescopes from 60mm to 235mm from Tecnosky of Italy
UK Distributor
Lunatico Dragonfly Automation Controller and Cloudwatcher weather station
80mm FPL-53 Triplet £829!
NEW! 125mm FPL-53 Doublet £1399!
60mm FPL-53 Doublet £399!
Solar Spectrum
The premium solution for rear mounted solar filters from the UK specialists in solar
Active temperature control for the highest performance. 0.3A-0.8A options in sizes from 19mm-46mm including Research Grade
Dedicated 0.4x and 0.7x telecompressors for wide field imaging
UK Specialist Partner
TEC
Experience the superb performance of APM's ED APO Binocular Range in sizes of 70, 82, 100 and 120mm
APM-LZOS Exceptional Apochromatic Refractors up to 510mm
NEW 130mm and 152mm models now available!
Outstanding FPL-53 and Fluorite Refractors and Binoculars up to 250mm from the Telescope Engineering Company
UK Exclusive Partner
APM APO
The UK specialists for APM
The ultimate mobile binocular? TEC's new 140 FPL-53 Triplet Super Binocular!
Dedicated to bringing you the finest quality equipment, service and support
info@astrograph.net
astrograph
QUALITY YOU CAN SEE
0843 330 4988
www.astrograph.net

Image PROCESSING

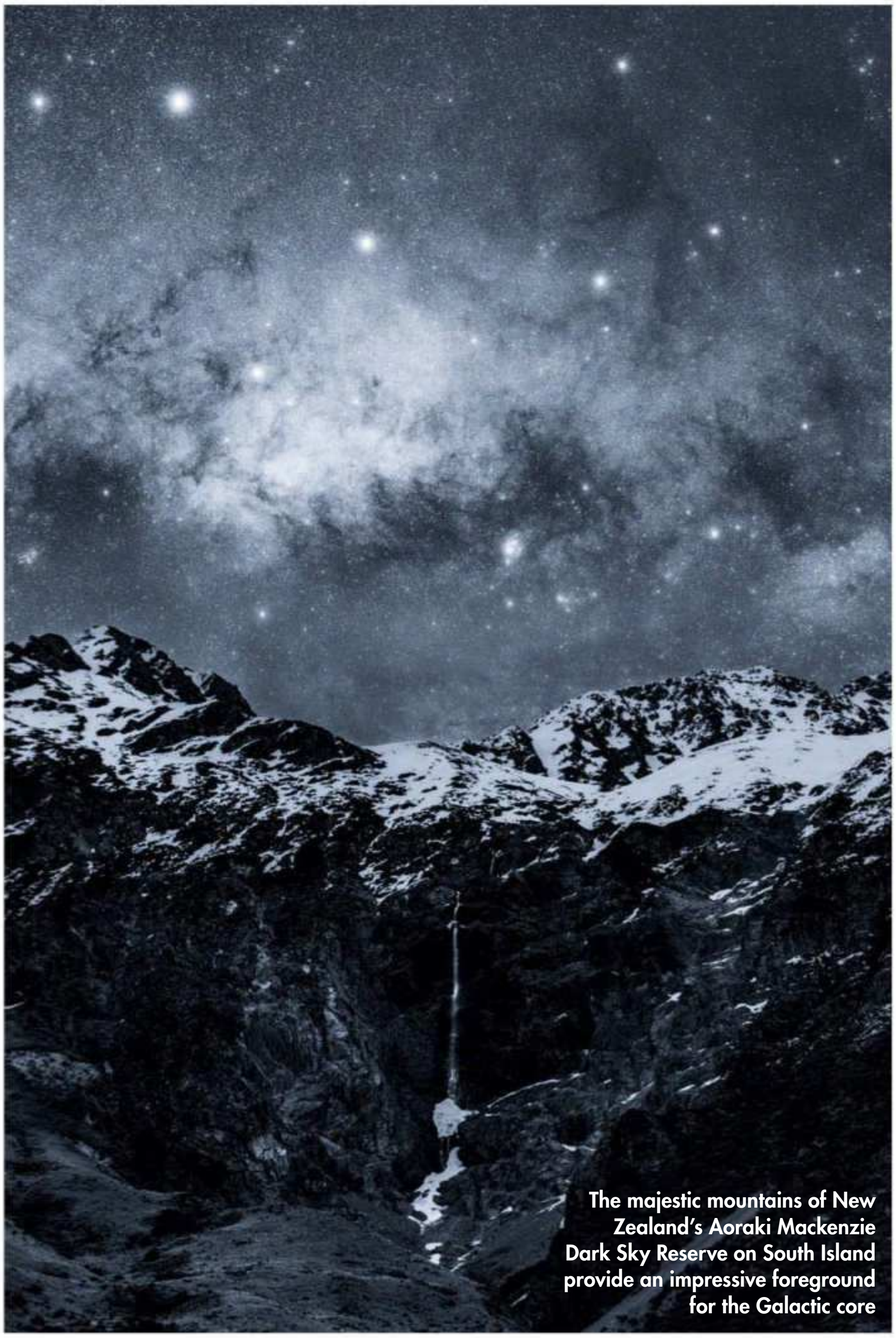
With
Chris Murphy

INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR

Advice from 2014's best newcomer winner

IAPY masterclass:
Shooting and combining landscape and sky

How to put together a stunning night scene by blending two separately shot images



The majestic mountains of New Zealand's Aoraki Mackenzie Dark Sky Reserve on South Island provide an impressive foreground for the Galactic core

ALL PICTURES: CHRIS MURPHY

Skyfall is an image I had in mind before shooting it. Having shot a similar image on the opposite side of the Godley Valley in New Zealand, I knew that this mountain waterfall would make a striking foreground for the Galactic core. The previous image was finished in black and white and I always had a monochrome image in mind when shooting this one.

So how would you go about producing an image like this? Because it was being shot in a dark-sky reserve only starlight illuminates the landscape. This means that in the darker landscape areas our signal-to-noise (SNR) ratio (photons hitting the sensor versus various electronic noise) is low and will produce a noisy, single image. Stacking images is a way to solve this problem. This means you need to commit to blending a final image of the sky with one of the landscape to prevent the Earth's rotation causing star trails.

Landscape first

This image was composed of two landscape-orientated frames from an 85mm lens, cropped to portrait orientation. The landscape requires a much longer exposure to gather enough signal to extract detail. So 13 two-minute exposure images at f/3.2 were stacked to let in a reasonable amount of light and retain sharpness. The ISO was set at 3200. If you're shooting with a lens that you're confident can be opened wider while retaining sharpness, it's always good to let more light in and raise the SNR. Generally, a longer exposure at lower ISOs is likely to be better than the equivalent total exposure at high ISOs.

Shooting the landscape gave time for

▲ The initial stacked landscape image. You can see the star trails, which is one of the reasons why the sky has to be shot separately

▲ This is the initial shot of the sky. As well as using a tracker to eliminate star trails, a smaller aperture also makes the stars sharper

the core to move into position. The sky was shot using a tracker for longer exposures without trailing and a smaller aperture for sharper stars. Exposure-wise, you don't need to use as wide an aperture or as much time to get a clean image of the sky, so this was five images stacked at f/4, 60 seconds at ISO 6400.

Processing was in Lightroom and Photoshop. Separate images were stacked using the median filter. In Lightroom this is done by selecting images to stack, right-clicking and selecting 'Edit' in 'Open as layers in Photoshop'. You'll want to check that your layers are aligned.

For the landscape shots, if you're confident they're aligned you can begin stacking. For tracked shots it's best to make sure. This can be done automatically by selecting all layers and 'Edit > Auto align layers'. If you have a lot of landscape in the frame you may need to mask it out and some lenses may need manual alignment. Once aligned, select all layers and right-click '> Convert to smart object'. This combines all layers before stacking. Select 'Layer > Smart Objects > Stack Mode > Median'. This will filter out noise and leave a much cleaner image.

Combining the images

When stacking is complete the two images need to be blended via masking. This can be tedious but if you want the highest quality for a certain image, there is no better way. For this image, the tops of the mountains were easy to blend. It was done by pasting the landscape image on top of the tracked sky image and adding a layer mask. The layer mask icon is at the bottom of the 'Layers' panel in Photoshop or under the 'Layers' menu.

Selecting the mask, choose a black brush and erase the blurry sky to reveal the tracked sky. You can use broad strokes for the most part but you need to zoom in and carefully trace around the edges where the landscape meets the sky. For mountains or straight structures this is quite easy; for trees, not so much. Once finished, you can flatten the image and save it in a format that retains all the information.

For the final look of this image, I used Lightroom. After using the saturation slider to convert to monochrome, I made contrast and clarity adjustments.

Finally, with desaturation leaving a warmer tone, adjustments were made to cool it using Split toning, adding cooler blue in both the shadows and highlights.

I think this image benefitted from some natural elements which enhanced the overall look, such as some light fog above the mountains which appears to enlarge the brighter stars and make them stand out. For me, this gives the effect of the dusty galactic core region being like snow from an approaching blizzard, or churning water from a larger waterfall above. S

CHRIS MURPHY is an award-winning, New Zealand-based astrophotographer

▲ In Photoshop, the landscape image is pasted over the sky image, then the landscape's blurry sky is removed using a layer mask

▲ For its final tweaks (including going monochrome), the image was taken into Lightroom for colour, saturation and clarity adjustments

Seeing is believing...

visionace®

with **vitamins A, B2** & **Zinc** which help to maintain

normal vision

Visionace® is based on extensive research and has been expertly formulated with over 20 nutrients including Bilberry and Lutein, with specific nutrients to help support your vision.

ORIGINAL PLUS OMEGA-3 MAX

Britain's No.1 Vitamin Company*

*Nielsen GB ScanTrack Total Coverage Unit Sales 52 w/e 17 June 2017.

From Boots, Superdrug, Holland & Barrett, supermarkets, chemists, health stores
www.visionace.com

† A beneficial effect is obtained with a daily intake of 250mg of DHA.

45 YEARS VITABIOTICS

Made in Britain

VITABIOTICS
SCIENCE OF HEALTHY LIVING

Scope DOCTOR

With **Steve Richards**

Our equipment specialist cures your optical ailments and technical maladies

► You can use the Seagull 1x-2x Right Angle Finder to make the polar aligning less of a physical strain

Flexibility problems give me trouble polar aligning up my Sky-Watcher 150P EQ3-2 Pro SynScan. Is there an auto align setup compatible with my mount?

SUSAN WALKER

Polar aligning an equatorial mount using a polarscope does require a certain amount of body contortion leaving you in an uncomfortable position for making intricate observations and adjustments. Sadly, the Celestron StarSense AutoAlign, which would be a solution, is not compatible with your mount. However, there are various solutions in the form of add-ons for your mount.

If you can take a laptop computer outside with you then there are two great ways to take the physical pain out of alignment. The budget route is to fabricate a small bracket using a plastic pipe to attach a cheap webcam to the eyepiece of the polarscope and observe the orientation of Polaris using the live view from the webcam. However, a much better method that is very simple to implement and requires no fabrication is to use the very popular QHY PoleMaster electronic polar alignment system which as a bonus will give you increased accuracy. Both of these solutions can be operated from a much more comfortable position with the laptop placed conveniently next to the mount.

If you don't have a laptop outside with you, then you could consider fabricating a bracket to attach a standard camera right-angled finder attachment to the eyepiece of your polarscope. The Seagull 1x-2x Right Angle Finder or the Neewer Perfect 1x-2x Right Angle Viewfinder could be used to improve the viewing angle by allowing you to look down through the polarscope rather than up.

ISTOCK

I'm a wheelchair user and I struggle to get to my telescope eyepiece because of the tripod legs. Any advice?

JON NOBLE

▲ A fixed-pier tripod would be an ideal setup for wheelchair users, allowing easy access to the telescope eyepiece

This must be a common problem and the very design of a standard tripod is at odds with wheelchair use. The ideal solution is to install a fixed pier at home as this has the minimum footprint of any support structure. A fixed pier has the added advantage of providing a very substantial base for your mount and if you use an equatorial mount in particular, setup time will be greatly reduced.

If this option is not available because you observe elsewhere and you require a solution that can be quickly assembled and dismantled then a portable pedestal mount would give you a greater degree of access than a standard tripod. If you can find one on the second-hand market, a TAL or Antares Portable Pedestal Mount would be suitable. Unfortunately, although good, these portable piers are not readily available, but you could get a welding shop to make one up for you based on photographs from the internet.

STEVE'S TOP TIP

What is a flat field?

Flat field correction is an important calibration technique that makes use of 'flat frames'. Flat frames are images shot at the same time as your actual astrophotography, with the camera kept in exactly the same orientation and the same focus position, but with the telescope pointing at a different, diffuse but evenly lit surface.

Applying flat frames to your images will compensate for variations in the pixel-to-pixel sensitivity of the sensor. However, flat frames also contain additional data, indicating the presence of vignetting and obstructions in the light path such as dust particles on glass surfaces; these faults will also be removed from images they are applied to.

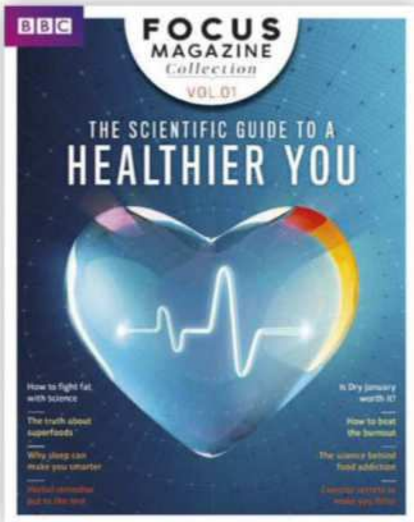
STEVE RICHARDS is a keen astro imager and an astronomy equipment expert

Email your queries to scopedoctor@skyatnightmagazine.com

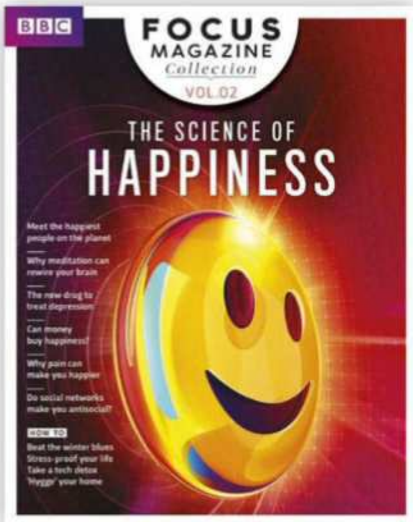
COMPLETE YOUR COLLECTION...

ONLY £9.99 EACH INCLUDING P&P*

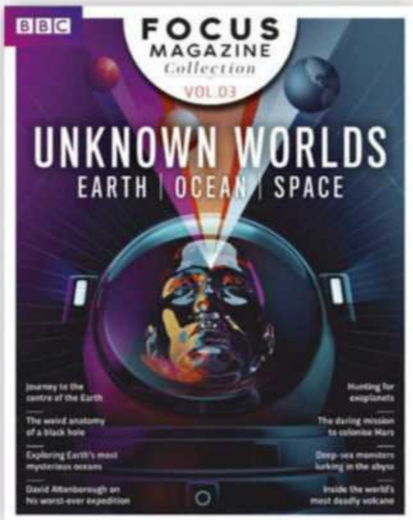
FROM THE MAKERS OF BBC **FOCUS** MAGAZINE



Get fit and healthy this spring! Discover the science behind what really makes you healthier and fitter, as experts reveal how to eat, exercise and sleep well.



Discover the science behind how to be happy, from stress-busting tricks to taking a tech detox. And find out why the happiest people on the planet keep smiling.



From the depths of the ocean to the depths of space, this special issue joins the expeditions that are pushing the boundaries on our quest to reach the final frontiers.

Find out how we can fix climate change, beat mass extinction and protect the planet. Experts reveal solutions to overfishing, plastic waste, flooding and air pollution.

Order online: **www.buysubscriptions.com/focuscollection**

or call us on **03330 162 138**† and quote **FOCSPEC**

†Calls from landlines will cost up to 9p per minute. Call charges from mobile phones will cost between 3p and 55p per minute but are included in free call packages. Lines are open 8.00am – 6.00pm weekdays and 9.00am – 1pm Saturday for orders only. *Subscribers to *BBC Sky at Night* Magazine receive FREE UK POSTAGE on these special editions. Prices including postage are: £11.49 for UK residents, £12.99 for Europe and £13.49 for Rest of World. All orders subject to availability. Please allow up to 21 days for delivery.

Sky at Night MAGAZINE

Reviews

Bringing you the best in equipment and accessories each month, as reviewed by our team of astro experts

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

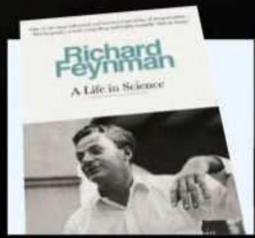
- ★★★★★ Outstanding
- ★★★★★ Very good
- ★★★★★ Good
- ★★★★★ Average
- ★★★★★ Poor/Avoid

94

Designed for wide-field astro imaging the Starwave 70 EDQ-R is a quadruplet scope with some impressive optics

SEE INTERACTIVE 360° MODELS OF ALL OUR FIRST LIGHT REVIEWS AT WWW.SKYATNIGHTMAGAZINE.COM

This month's reviews



WWW.THESECRETSTUDIO.NET X 4

Find out more about how we review equipment at **www.skyatnightmagazine.com/scoring-categories**

FIRST **LIGHT**

See an interactive 360° model of this kit at www.skyatnightmagazine.com/bresserAR90

Bresser AR90/500 guiding kit

WORDS: TIM JARDINE

An all-in-one solution to keeping your telescope trained on its targets

VITAL STATS

- **Price** £356.00
- **Optics** Bresser Messier AR-90s f/5.5 multi-coated achromat
- **Aperture** 90mm
- **Focal Length** 500mm
- **Length** approx 550mm assembled
- **Guide Camera** 2.1 megapixels Bresser GPCMOS02000KPA colour
- **Sensor** Sony IMX290 CMOS
- **Connections** USB 2.0, ST4
- **Min/Max exposure** 0.066ms-16 mins
- **Extras** 6x30 finderscope, 26mm Plössl eyepiece, 1.25-inch star diagonal, ToupSky software, protective bag
- **Weight** 2kg
- **Supplier** Telescope House
- **Tel** 01342 837098
- **www.**telescopehouse.com

SKY SAYS...
A cost-effective, simple answer to the question, "What do I need to start auto-guiding?"

Deep-sky astrophotography is becoming ever more popular among amateur astronomers and many observers dip their toes into the hobby using a camera on their telescope and mount. It soon becomes apparent, though, that taking stunning, long-exposure photographs requires some extra equipment and a process known as 'auto-guiding'. Taking that next step has been easier thanks to the introduction of Bresser's new AR90/500 guiding kit, which aims to provide a simple, everything-in-the-box solution to auto-guiding.

In simple terms, auto-guiding is a method of ensuring that a telescope remains pointed precisely at an object being observed, following it as it moves across the sky. Even very expensive mounts can benefit from automatic guidance, as several factors influence how well a mount will hold steady on its target and enable you to take long-exposure pictures that aren't spoiled by star trails.

The AR90/500 consists of a 90mm achromatic telescope with a focal length of 500mm, a 6x30 optical finderscope, a Bresser GPCMOS02000KPA colour guide camera, a 26mm Plössl eyepiece, a 1.25-inch diagonal, a universal clamp, a tube clamp, cables, a soft bag and ToupSky imaging software.

The 90mm telescope is firmly attached to the main setup and acts as a separate 'guidescope'. The little camera on the guidescope is focused on a star near your photographic target, and it relays information via a laptop or PC to keep your mount locked onto your desired object.

Keeping things light

We were pleased to see, then, that the 90mm telescope in this kit is lightweight. In fact, the whole assembly only added around 2kg to our telescope and camera rig. In general, the less weight a mount has to carry, the more accurate it will be.

Having decided to mount the AR90/500 on top of our setup, we used the supplied bolts and clamp, attached to our own rail, to hold the Vixen-style dovetail in place. Although the guidescope was not perfectly aligned with the main telescope, and there's no method of adjusting the alignment once the clamp is in place, it was close enough for our purposes. Finding a rough focus position is made ▸

Multi-tasking camera

In addition to its capable performance as a guiding instrument, the colour CMOS camera that comes with the kit can also operate as a lunar, planetary or even deep-sky camera. Using a backlit, Sony IMX290 sensor with a high resolution, 2.1 megapixels (1,936x1,096 pixel) array, the camera can record video at 15fps, for lunar and planetary imaging, or individual exposures up to 16 minutes long. It fits directly into a standard 1.25-inch eyepiece holder and includes a C-Mount extension tube. To test the camera as a standalone instrument, we transferred it to an 11-inch SCT telescope and pointed it towards the Moon. Although high in the sky, the pleasing detailed on some features, including Vallis Alpes. Dropping down to the Trapezium region in Orion, we were treated to a rich, colourful view of the nebula surrounding the star group, indicating that the camera is sensitive to both hydrogen (red) and oxygen (green/blue) wavelengths.

WWW.THESECRETSTUDIO.NET X 6

AR90s telescope

With a 90mm aperture, clear multi-coated achromatic optics and 500mm in focal length (f/5.5), the guide telescope provides good star images. It incorporates graduated internal baffles for better contrast, a fixed dew shield and a rack and pinion focuser. A 4-inch wide clamping ring holds the tube steady, helping to reduce unwanted flexure.

ST4 guide port

The rear of the guide camera includes a standard ST4 port and a cable to attach directly to a mount, which typically offers the simplest guiding option in conjunction with a computer. Alternatively, pulse guiding removes the need for the ST4 cable, but requires extra software and possibly hardware.

Universal clamp

Designed to attach directly to Bresser or Explore Scientific telescopes, this universal clamp has multiple fixing points, enabling it to be easily and securely bolted to a suitable bar or fixture on the main telescope. Two fixing bolts are provided, and four of the fixing points accept ¼-20 threaded fittings.

FIRST LIGHT

SKY SAYS...
Now add these:
1. Explore Scientific 208mm f/3.9 Photo Newtonian - Hex-Focus
2. Explore Scientific EXOS-2 PMC-Eight Go-To mount
3. Altair Hypercam 183C V2 USB3.0 colour deep-sky imaging/EAA camera

Additional accessories

The kit also comes with a basic straight-through finderscope which attaches to the AR-90s; a 1.25-inch diagonal mirror; a 26mm Plössl eyepiece in a protective case, which we found useful while setting up and aligning the telescope; a handy telescope bag; a CD copy of Stellarium planetarium software; and even a mini planisphere.

▸ easier by using the kit's basic 26mm Plössl eyepiece, which we then swapped for the guide camera itself. It would have been preferable if the camera could have been used straight through, but we found that it's only possible to focus the guide camera if the included 1.25-inch diagonal mirror is used. Setup was fairly quick because of our experience with auto-guiding, but newcomers may be frustrated by the lack of useful instructions.

Having installed the camera software from the accompanying CD, we were pleased to see that the camera was immediately recognised in PHD2, our preferred auto-guiding software, although the camera is compatible with all major auto-guiding software packages.

Ready to go, we slewed to our first target, the Rosette Nebula near Orion. Right away we were presented with a choice of stars to guide on, picked out by the sensitive little camera. It's worth mentioning that each star had a slight halo, which we believe is the result of using a colour camera on an achromatic telescope. This does not affect the guiding software, though, and soon our first five-minute test exposure was underway. When we checked the star shapes, they were tight and round. Thus emboldened, we increased the exposure length to 10 minutes, and then to 15 minutes, and the AR90/500 performed its task admirably. In fact, over successive sessions on a variety of nights – and no matter where in the sky our target was – our imaging telescope was held accurately on target, allowing us to get on with the real business at hand: deep-sky astrophotography.

By bringing together everything you need to take astrophotography to the next level, the AR90/500 provides a cost-effective, simple answer to the question, "What do I need to start auto-guiding?"

Software bundle

ToupSky imaging software is included on the driver disk and allows full control of the CMOS camera for lunar, planetary or deep-sky imaging. Video or Trigger mode offer numerous options, ensuring camera settings suit the target and sky conditions, along with 8- or 12-bit imaging and colour balancing.

▲ A single, 15-minute exposure, taken using the Bresser AR90/500 kit, 150/1,000mm apo, h-alpha filter and Atik 11000 camera. Note the crisp, round stars and absence of any trailing

Verdict

Build and design	★★★☆☆
Ease of use	★★★☆☆
Features	★★★★☆
Guide star quality	★★★☆☆
Optics	★★★☆☆
OVERALL	★★★☆☆

FIRST **LIGHT**

See an interactive 360° model of this scope at **www.skyatnightmagazine.com/starwavequad**

Altair Starwave 70 EDQ-R quad apo imaging refractor

WORDS: GARY PALMER

A four-lensed, lightweight scope designed for easy, wide-field astro imaging

VITAL STATS

- **Price** £1,150
- **Optics** Air-spaced quadruplet
- **Aperture** 70mm
- **Focal length** 350mm, f/5
- **Focuser** CNC rack and pinion with fine focus
- **Extras** Tube rings, dovetail bar, finder bracket
- **Weight** 1.4kg
- **Supplier** Altair Astro
- **Tel** 01263 731505
- **www.**altairastro.com

Astrophotographers have an ever-growing wishlist of new kit as technology keeps advancing. The new Starwave 70 EDQ-R quad apo imaging refractor is another telescope to add to that list.

The 70 EDQ-R has a 350mm, f/5 focal length and is aimed at wide-field imaging. With the right camera attached it can fit some very large objects into its field of view. A quadruplet design of telescope is nothing new but some very careful attention to detail has made this telescope a lot more user friendly.

Quadruplet telescopes are made up of four lenses. The front three are for colour correction while a fourth lens at the back flattens the field of view. The flattener being built in makes for a more stable imaging setup rather than having to insert a separate flattener in at the focuser end. The aim is to achieve round stars right into the far corners of your images and good colour correction across the entire image.

SKY SAYS...
A user-friendly scope with superb optics that makes astro imaging a real pleasure

Where the quad differs from a normal refractor is that the rear end terminates in an M42 thread so that you can attach a camera directly to it, or, in the case of a DSLR, by using a T-adaptor. With all telescopes, temperature changes can make a big difference to images. In a cold environment it is recommended that you heat the tube slightly. This will help with the difference in glass and tube temperature and it can easily be achieved with a dew strap around the tube on a moderate setting.

Surprisingly light

Once we'd unpacked the 70 EDQ-R, the first thing we noticed about the telescope is how light it is: with a Canon EOS 70D DSLR camera attached it weighed just 2.1kg. This really does make it a grab-and-go telescope for even the smallest of mounts. Even with a smaller aperture, the change in CMOS cameras over the last few years means images of all sorts of objects are achievable with this telescope. That makes it an ideal travel scope ▸

Top of the glass

High-quality Japanese ED S-FPL53 glass is used for good colour correction. This, coupled with super-high transmission coating on all air-to-glass surfaces, ensures high contrast in images. The four-lens system gives a flat-field image circle of around 42mm at 350mm focal length, with a focal ratio of f/5. Having the correcting lens built in helps with the control of dust, while not having to attach correctors in front of the camera means less equipment to take out with you on imaging sessions. When focused on infinity, the camera sensor is automatically at optimum spacing.

Using two ED elements in the optical arrangement gives minimal vignetting, which only starts to show in the corners of a full-frame 35mm field. The roundness of the stars remained well-defined right into the corners of the image too. When coupled with a larger format camera or DSLR the 70mm design allows for excellent wide-field images. Wide-field views of the Whirlpool Galaxy, the Andromeda Galaxy and the Pleiades gave pleasing detail in our tests.

WWW.THESECRETSTUDIO.NET X 4

Tube rings

Lightweight aluminium tube rings and a Vixen dovetail bar are included. The dovetail bar has an elongated slot at one end for easy adjustment of the rings. This makes balancing the position of the telescope easy on any motorised mount. The bar has a thread to mount on a tripod and ball mounts.

Finder shoe

Having a finder shoe is a nice touch as they're often not included on smaller refractors. Based around a Sky-Watcher finderscope, the shoe is quite generous in size and doesn't interfere with the rotation of the camera. It can also be used to mount a small guidescope or camera.

M42 rear adaptor

The M42-threaded rear adaptor is fully rotatable and makes framing targets really easy. All locking pins are nylon coated for secure locking. On the inside of the flange are adjusters to allow for sensor tilt. With the tilt adjuster set to zero the back focus is 66.78mm.

Focuser

A high-quality rack and pinion focuser with a micro focuser for fine adjustment makes focusing easy. It can be fully rotated allowing the telescope to be mounted on a range of equipment without the focus knobs getting in the way. The focuser can support even the heaviest of cameras with nice smooth adjustment.

FIRST LIGHT

Dew shield

A sturdy built-in, fully retractable dew shield helps keep dew down to a minimum in average temperatures. It is coated black on the inside to stop any stray light entering the telescope. The dew shield has adjustment screws to make a firm fit to the tube.

▸ and a good option to take with you on longer trips instead of a set of camera lenses.

Build quality in general is very good, and it comes with quite a lot as standard. The tube is made from lightweight alloy with extending dew shield and it comes with a good set of adjustable tube rings on a dovetail bar. A quality rack and pinion focuser with nice, smooth movement adds to the quality feel. The only thing we did find that let it down was a loose lens cap that kept falling off.

While the 70 EDQ-R is primarily a telescope for astrophotography it can be used with an eyepiece by adding a 40mm extension to the back thread. For beginners this may make it easier to align finderscopes and mounts when first setting up.

The first target we imaged was the Andromeda Galaxy using a finder-guider configuration on a portable tracking mount set on a tripod. The camera was a Canon DSLR setup using the basic EOS capture on the computer. We took 20 three-minute images which captured lots of detail in the dust lanes with round stars and vibrant colours. For such a short amount of imaging time we were happy with the end result. The same process was repeated on a subsequent night with the Pleiades as our target, again revealing plenty of structural detail.

Changing to CMOS cameras was simple and with M42-threaded extension rings on the camera it was easy to focus on the screen. When you're using a mono camera, there's ample space to attach a small filter wheel in the imaging train if you need it. Images of the Moon with a Hypercam 183C showed a lot of detail for the aperture.

The 70 EDQ-R is a very good addition to anyone's imaging setup and makes it very easy to capture good images with the minimal amount of effort. S

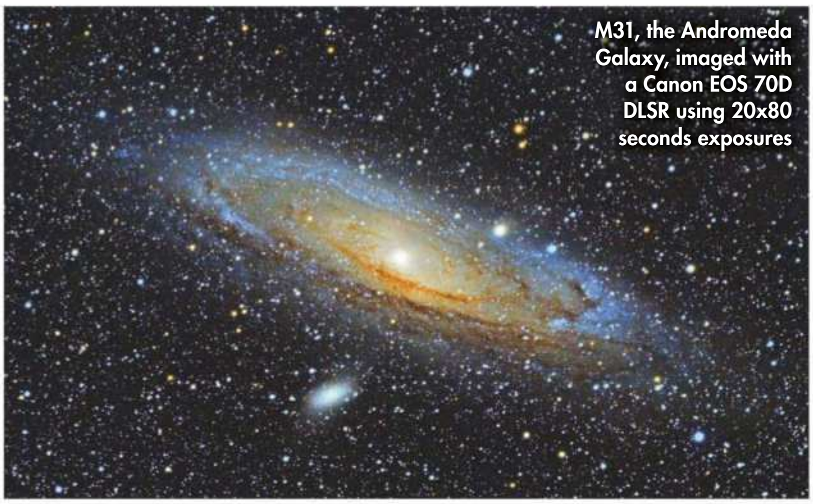
Verdict

Build and design	★★★★☆
Ease of use	★★★★☆
Features	★★★★★
Imaging quality	★★★★☆
Optics	★★★★★
OVERALL	★★★★☆

WWW.THESECRETSTUDIO.NET, GARY PALMER X 2

SKY SAYS...
Now add these:
1. Altair Hypercam 183C astro imaging camera
2. Altair 60mm guider & GPCAM2 mono camera kit
3. iOptron CEM25P Go-To imaging mount

◂ M45, the Pleiades, imaged with a Canon EOS 70D DSLR camera using 20x180 second exposures



M31, the Andromeda Galaxy, imaged with a Canon EOS 70D DSLR using 20x80 seconds exposures

See an interactive 360° model of these eyepieces at www.skyatnightmagazine.com/omegonpan2

Omegon Panorama II eyepieces

WORDS: STEVE RICHARDS

A smart set of lenses that open up the sky into glorious widescreen

VITAL STATS

- **Price** £199-£229
- **Focal Length** 5mm, 10mm, 15mm, 21mm
- **Apparent field of view** 100°
- **Eye relief** 13mm-20mm
- **Optical elements** 7mm-9mm
- **Barrel size** 1.25-inch (5mm and 10mm lenses), 2-inch (15mm and 21mm lenses)
- **Supplier** Astroshop.de
- **www.**astroshop.de
- **Tel** +49 8191 940491

For anyone used to using a typical Plössl eyepiece, the ultra-wide field of vision offered by these Omegon Panorama II eyepieces will open up a whole new observing experience. Rather than the feeling that you're observing through a tube, you'll be able to soak up the detail across a far wider expanse of sky.

Omegon's new eyepiece collection comprises oculars with focal lengths of 5mm, 10mm, 15mm and 21mm, giving them a wide range of uses. As with other eyepiece collections, the shorter focal lengths are most suitable for observing Solar System objects and galaxies while the longer focal lengths are more suited to open clusters and extended nebulae. However, that's not a rule written in stone and there's plenty of pleasure to be found in observing galaxies in their natural habitat in a wide-field context, just as there's always something magical about observing the whole of a quarter Moon isolated in space.

The collection is neatly divided into two styles of eyepiece: 2-inch barrels for the 21mm and 15mm versions and 1.25-inch barrels for the 10mm and 5mm. This means that your telescope will need a 2-inch eyepiece holder and a 1.25-inch eyepiece adaptor to accommodate both versions. There are undercuts in both barrel types. As the true field of view increases, there comes a point where the field stop of a 1.25-inch eyepiece becomes the limiting factor in the width of view that is possible. A 2-inch eyepiece overcomes this limitation as the diameter of its field top is larger than that of a 1.25-inch eyepiece.

SKY SAYS...
Great lenses for taking in a wider expanse of the sky without sacrificing on viewing quality

What's in the box?

The Omegon Panorama IIs are supplied in a substantial retail box and beautifully finished in gloss black with two red stripes looping them. Two rubber grips give handling confidence even when you're wearing gloves. Dust covers are included for both ends of each eyepiece and there's a microfibre cloth for cleaning the lenses. The dust caps for the eye lenses are tapered which made them a pain to pick up. Weighing from 322gm to 709gm, the eyepieces have a satisfying heft to them.

The 21mm and 15mm pair are parfocal as are the 10mm and 5mm pair, but you need to rack the ▸

Eyes even wider open

Two important attributes determine your choice of eyepiece for a particular observation: the focal length and the apparent field of view (AFOV) in degrees (°). The focal length determines the magnification of a particular telescope (magnification = focal length of telescope/focal length of eyepiece) and the AFOV determines the true field of view observed depending on the magnification (true field of view = AFOV/magnification).

A standard Plössl eyepiece, like those often bundled with new telescopes, comprises four lens elements and produces an AFOV of around 52°. The Omegon Panorama IIs have between seven and nine lens elements with a large eye lens allowing for some clever optical manipulation to nearly double that AFOV to 100°. As a result, they produce a really wide true field of view.

As well as allowing you to see more of a large object through the telescope, a really wide field of view provides a wonderfully immersive experience giving you the feeling of being part of the view you're observing.

WWW.THESECRETSTUDIO.NET X 4

Multi-coating

Multi-coating the individual lens elements increases light transmission through the eyepiece by reducing the reflections that would otherwise decrease the contrast in the view. The coatings were applied to an extremely high standard with no visible blemishes and displayed a classic green tinge with hints of purple deeper into the eyepiece body.

Rubber grip

Great care needs to be exercised when handling eyepieces in the cold and dark, and heavier eyepieces increase the risk of an accident. Each of the Omegon eyepieces has two bands of 15mm-deep chunky rubber grip surrounding the widest parts of their bodies. The well-designed, raised surface provides a very non-slip grip.

2-inch and 1.25-inch barrels

The 21mm and 15mm eyepieces have 2-inch barrels and the 10mm and 5mm have 1.25-inch barrels. The barrels are provided with undercuts to help protect them from slipping out of the eyepiece holder in the diagonal. The 2-inch undercuts were a good match for our compression rings but the 1.25-inch ones were too narrow to be effective.

Filter thread

The Omegon eyepiece barrels are threaded to take 2-inch or 1.25-inch filters as appropriate. Many celestial objects respond well to the use of special filters – such as narrowband Oxygen III (OIII) and ultra high contrast (UHC) for deep-sky or #80A blue filter for the Moon and planets – as these can increase the contrast in the view.

FIRST **LIGHT**

▸ focus in by an extra 10mm when moving from the 2-inch to 1.25-inch eyepieces.

We tested the eyepieces in two of our refractors, a Williams Optics FLT 98 and a Megrez 72FD observing a range of objects. Even with the rubber eye cups folded up we found eye placement a little tricky at first but soon got into the swing of it and with close scrutiny we were able to see the whole field of view, although the field stop was not particularly distinct. With the generous eye relief of the 10mm, 15mm and 21mm lenses we could just see the field edge when wearing spectacles with the rubber eye cup in the folded-down position but struggled to do the same with the 5mm eyepiece.

We enjoyed some wonderful views of the Moon and one clear night coincided with the appearance of the Lunar X and Lunar V that stood out stunningly using all four eyepieces. Our most memorable lunar observations were the sublime views that we achieved using the 5mm eyepiece to take in the Montes Apenninus followed by Huygen's Sword (Rupes Recta).

We trained the 21mm and 15mm eyepieces on the Pleiades star cluster and were rewarded with a sparkling, sharp view through both. Moving to M42, we used the 5mm eyepiece to look deep into the Trapezium region and also enjoyed some wonderful views of the tendrils of nebulosity that surround this area using the 10mm eyepiece.

On 23 February, the Moon was close to Aldebaran and this allowed us to star-test the eyepieces under harsh observing conditions. We found that good star shapes extended to at least 90 per cent of the field of view and extraneous light from the close-by Moon was barely apparent.

We really enjoyed using these eyepieces and heartily recommend them to intermediate and more experienced observers. S

Fold-up rubber eye cup

Each eyepiece is equipped with a soft rubber fold-up eye cup that is used to obtain the best views from any eyepiece by helping to keep stray external light at bay. These cups provide a comfortable resting point for positioning your eye accurately over the exit pupil or spectacle wearers can fold them down.

Verdict

Build and design	★★★★☆
Ease of use	★★★★☆
Extras	★★★★☆
Eye relief	★★★★☆
Optics	★★★★☆
OVERALL	★★★★☆

SKY SAYS...
Now add these:

1. Omegon 5-in-1 optics cleaning set
2. UHC 1.25-inch filter
3. Omegon Pro 1.25-inch LRGB filter set

WWW.THESECRETSTUDIO.NET X 2

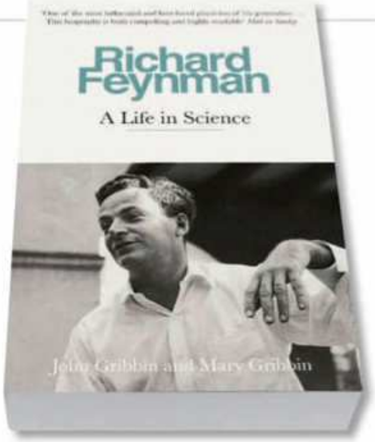
Books

New astronomy and space titles reviewed

RATINGS

★★★★★ Outstanding
★★★★☆ Good
★★★☆☆ Average
★★☆☆☆ Poor
★☆☆☆☆ Avoid

Richard Feynman
A Life in Science



John Gribbin and Mary Gribbin
Icon Books
£9.99 ● PB

If you've never heard of Richard Feynman, go read this book. It's not just a great biography of one of the most flamboyant scientists of the 20th century, but also a wonderful introduction to quantum electrodynamics (QED), the theory describing the interaction of light and matter to which Feynman was a major contributor.

Richard (Dick) Feynman (1918-1988) became known to the general public only in early 1986, when he was on the presidential commission that looked into the fatal Challenger Space Shuttle disaster. For the eyes of the world, he carried out a simple experiment showing how rubber O-rings become brittle at low temperatures, thereby revealing that cold weather prior to launch had ultimately led to the failure of one of the Shuttle's O-ring seals, which caused the disaster. By then, Feynman had already helped develop the atomic bomb, quantum electrodynamics and the theory of superfluidity. In 1965, he shared the Nobel Prize in Physics with Julian Schwinger and Shin'ichiro Tomonaga.

Feynman (right) receiving his Nobel Prize in Physics in Stockholm, 1965

KEYSTONE PICTURES USA/ALAMY STOCK PHOTO

However, among other physicists, Feynman is mainly remembered for his inspiring and crystal-clear physics lectures (still available on the internet), for his kindness and playful character and for the sheer joy he experienced in everything scientific. He was not your stereotype of a fusty physics professor, but a boyish explorer with an insatiable thirst for knowledge, a knack for cracking safe codes and a love of bongo drums.

Feynman wrote two popular books about his own life (*Surely You're Joking, Mr Feynman!* and *What Do You Care What Other People Think?*), but this biography by acclaimed science writers John and Mary Gribbin (republished to mark the centenary of Feynman's birth) is more complete and better balanced. In alternate chapters, it focuses on episodes in his life and on the science he was involved with, but there's never really a clear distinction between the two. After all, Richard Feynman lived science.

Hopefully, young students will continue to be inspired by this remarkable physicist. After reading this fine biography, you'll agree that we could definitely use a new Feynman.

★★★★☆

GOVERT SCHILLING *is an astronomy writer and author of* Ripples in Spacetime, *the story behind the discovery of gravitational waves*

TWO MINUTES WITH John Gribbin

Why is Richard Feynman such an important figure?
He was a first-rate scientist and more importantly a first-rate teacher and communicator. He reached out to the world, explaining physics in an easily understood way and showed that scientists aren't robots in lab coats but human beings who like a good time (and playing the bongo drums).

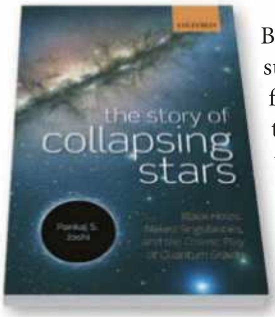
How did Feynman contribute to the Challenger disaster investigation?
Feynman was independent of NASA and known for his sharp brain and outspoken honesty. Following some hints from a colleague, Feynman found the immediate cause of the accident and drew attention to the mismanagement and bad practices that had caused it. This was not what the authorities wanted to hear, and they tried to keep him quiet, but he insisted on publishing his findings. NASA was never the same again, but in a good way.

How would you describe Richard Feynman, the person?
We never met Feynman, but we met many of his friends and colleagues, who revealed to us an image of a man who was sociable, fun to be with and honest. He got more pleasure out of things he was not expected to be good at (like painting or cracking codes) than his day job. On more than one occasion he solved a major physics problem, stuck the paperwork in a drawer and forgot about it until someone else solved the same puzzle and published it. In a sense, he was the last great amateur scientist.

JOHN GRIBBIN *is author of such books as* 13.8 *and* The Universe: A Biography

The Story of Collapsing Stars

Pankaj S Joshi
Oxford University Press
£14.99 ● PB



Black holes are surely the most fascinating objects the Universe has to offer. These superdense points of concentrated mass, surrounded by event horizons from which not even light can escape, have haunted our imaginations for decades.

The Story of Collapsing Stars is not just another introduction to black holes. Author Pankaj Joshi is one of a growing number of scientists arguing that long-standing ideas about these cosmic monsters may be wrong – or, at least, considerably oversimplified.

And so Joshi sets out to introduce, as painlessly as possible, the concept of naked singularities. These are regions where the distortion of space-time around the dense singularity point (as predicted by general relativity) can remain exposed to view rather than sealed away behind an event horizon. Such objects, Joshi shows, could be formed during the deaths of certain types of massive stars. What's more, if they could be observed, they would provide a powerful demonstration of 'quantum gravity', the hypothetical theory that unites gravity with the other fundamental forces binding matter on smaller scales.

The author approaches this daunting subject in a meticulous fashion, unfolding the story from first principles over 10 well-organised chapters, valiantly avoiding mathematical equations throughout, and raising many intriguing questions from the frontiers of physics and cosmology.

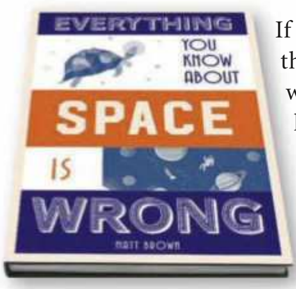
However, the book sadly falters in terms of readability, due mainly to an academic and overly repetitive writing style. Getting to grips with such a complex topic was always going to be a tall order, but a little more copy editing could really have helped this book fulfil its potential.

★★★☆☆

GILES SPARROW *is a science writer and a fellow of the Royal Astronomical Society*

Everything You Know About Space is Wrong

Matt Brown
Batsford
£9.99 ● HB



If a book promising that it "boldly goes where no nitpicker has gone before" appeals to you, then Matt Brown's latest offering will not disappoint.

Everything You Know About Space is Wrong is delightfully humorous and scientifically accurate in its space pedantry.

The book sets out to right inaccuracies and misconceptions about space partly as a "springboard to higher things", pledging fun along the way. Brown's lively style and choice selection of factoids and anecdotes fully delivers. Who knew the myth of the Great Wall of China being the only human construction visible from space dates back to the writings of 17th century English antiquarian William Stukeley? Or that the discoverer of Pluto, Clyde Tombaugh, will be the first human to leave our Solar System and reach interstellar space? A sample of his ashes is aboard NASA's New Horizons probe, which is currently somewhere deep in the Kuiper Belt.

Brown also includes some cheeky toilet humour, which will no doubt delight younger readers. Apparently 96 plastic bags of poo, or 'defecation collection devices', were left behind on the Moon by Apollo astronauts. Then there's an hilarious 'whodunnit' moment from a NASA transcript of the astronauts aboard Apollo 10 discussing an escaped floating number two. Even the most serious reader may have difficulty keeping a straight face at astronaut Tom Stafford's defence statement: "Mine was a little more sticky than that."

For the space literate, everything you know about space may not be wrong at all. That said, already knowing your space myths from space facts will not detract from a thoroughly enjoyable read.

★★★★☆

SHAONI BHATTACHARYA *is a science writer and journalist*

Big Bang: A Ladybird Expert Book

BOOK OF THE MONTH

Marcus Chown
Michael Joseph
£7.99 ● HB

Ladybird Expert Books rarely disappoint, and *Big Bang* by Marcus Chown certainly doesn't. This beautiful pocket-sized book discusses exactly what the Big Bang is, how this theory came about and how it has evolved over the years given the physical evidence, such as the 'bolt-ons' of dark matter, dark energy and inflation.

It's remarkable that the author manages to cover everything you would expect in so few pages. Also impressive is the thought that has gone into the book in terms of its flow and layout. Each page of copy is separated by a stunning retro image, which really helps to demarcate the concepts and stop the reader from feeling overwhelmed.

At times, but not often, the wonderfully concise writing dances around the fine line of needing more explanation. However, the author never loses the audience. Yes the concepts are challenging, but the book does explain every term it introduces and is accessible to a non-expert. There are also some lovely analogies throughout which I will be borrowing for the next time I introduce certain topics, my favourite being a tanker emerging from the fog to explain the epoch of last scattering.

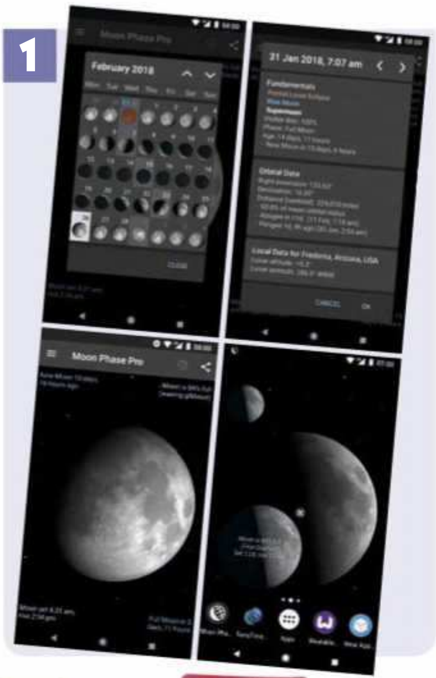
Overall, this book is a fun introduction to the Big Bang and one that you can read in a short time; perhaps on a commute to work. Be warned, though – it is likely to stimulate your interest in cosmology and leave you eager to learn more.

★★★★★

DR LAURA NUTTALL *is a Sêr Cymru MSCA COFUND fellow at Cardiff University and a member of the LIGO Scientific Collaboration*

Gear

Elizabeth Pearson rounds up the latest astronomical accessories



1 Moon Phase Pro app

Price £0.89 • **Supplier** Moon Phase Pro
http://moonphasepro.com

Check the Moon's phase, position, rise time and more with this Android app. A 3D model shows what the Moon will look like and where it will be at any given location and time. Available from Google Play and the Amazon Appstore.

2 Heat Holder Socks

Price £4 • **Supplier** Go Outdoors
0330 008 1555 • www.gooutdoors.co.uk

Keep your feet toasty during late night observing sessions with these socks. A special yarn traps in the heat.

3 TS Optics 3-inch rack and pinion focuser

Price £359.90 • **Supplier** 365 Astronomy
0203 384 5187 • www.365astronomy.com

This ultra-smooth focuser can hold heavy loads without tilting. The focuser end attaches to standard threads and the camera side has both 1.25- and 2-inch connectors.

4 Sky-Watcher EvoGuide 50mm guidescope

Price £169 • **Supplier** Telescope House
01342 837098 • www.telescopehouse.com

The EvoGuide is a high-quality, f/4.8 guidescope which also doubles as a finder, a camera lens or even a travelling scope. It comes with a mount and two collimation rings.

5 Planet Plates

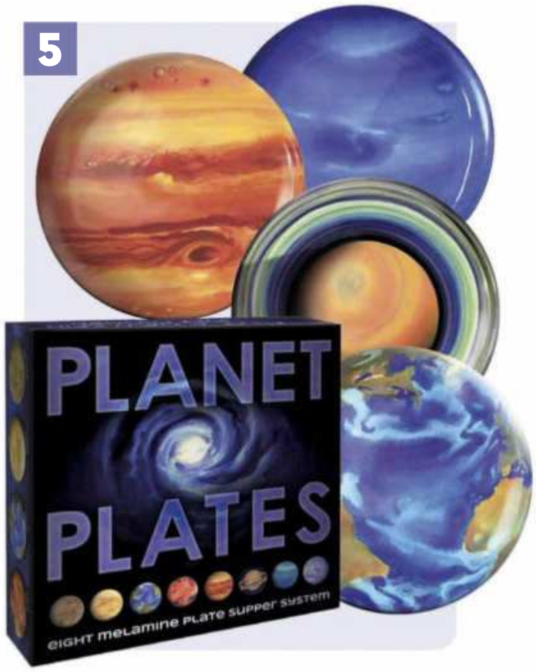
Price £31.99 • **Supplier** Nuku
01244 563152 • www.nuku.co.uk

Each of the eight plastic plates in this set is decorated with a watercolour image of a planet. Dishwasher safe, they're perfect for your next star party.

6 Hermetic Case Green

Price from £37.43 • **Supplier** Geoptik Astronomy • www.geoptik.com

Keep your scope safe when you're on the go with a case that protects against breakage, water and dust. A pressure valve even ensures that your kit isn't damaged during air travel.



WHAT I REALLY WANT TO KNOW IS…
Was our Sun born in a bubble?

Vikram Dwarkadas suggests that the Solar System could have formed in a shell blown out from a hot massive star

INTERVIEWED BY PAUL SUTHERLAND

Stars form inside great clouds of gas and dust, like stellar nurseries. This is well known. We clearly see it happening in the Orion Nebula, for example, as well as many others.

I have been leading a team trying to understand the high level of aluminium-26 and low level of iron-60 in the early Solar System. Our conclusion is that it happened because the Solar System was born inside a bubble blown out by a massive star nearing the end of its life.

For several decades, astronomers have believed that a supernova was located near the Sun and the Solar System when they formed. However, evidence found in meteorites tells us that this is not the case. Scientists have studied many meteorites that are pristine remnants left over from the formation of the Solar System four-and-a-half billion years ago. They show that at that time there were high levels of the element aluminium-26 compared to what was in the galactic background. Something nearby must have supplied it.

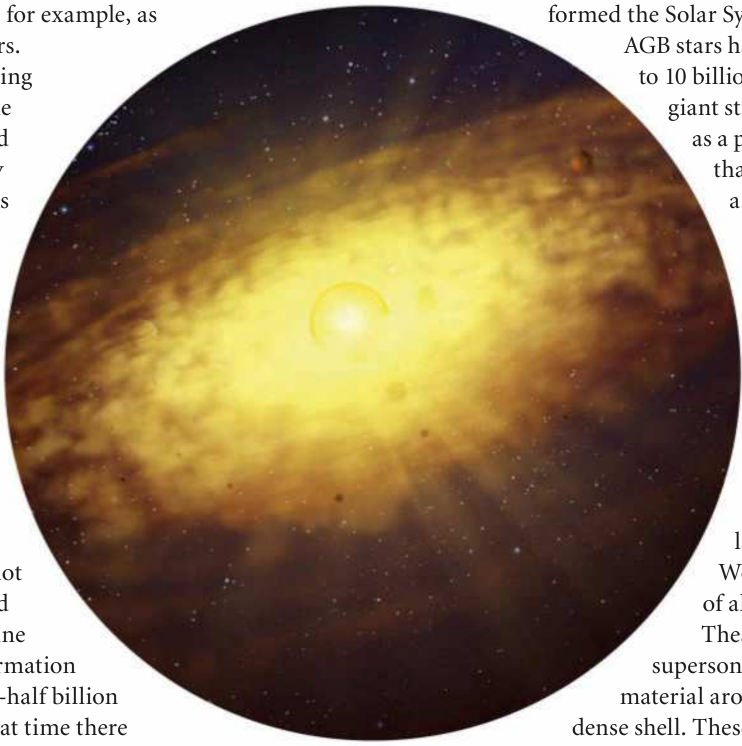
A supernova would produce aluminium-26. However, it would have also produced the isotope iron-60, yet studies of the meteorites show much less of that isotope than we would expect to find.

I predict a Wolf-Rayet

So if not a supernova, then what else could have provided the building materials for the Solar System? We looked at two alternatives: a Wolf-Rayet star and an AGB star.

A Wolf-Rayet star is an extremely hot, luminous star, 40 to 50 times more massive than the Sun, that is nearing the end of its short life of four to five million years. It has lost its hydrogen and may eventually end its life as a supernova.

An AGB star is a less massive star in the final stages of its evolution, similar to a red giant. It is named after the Asymptotic Giant Branch of the Hertzsprung-Russell diagram, which charts stellar evolution. It is thought that the Sun will become an AGB star. We had to look at which of these types of star could release the material in just the right amounts and get it into the cloud that formed the Solar System.



It was once believed that a nearby supernova had an influence on the birth of the Solar System but it now seems more likely that a Wolf-Rayet star played a role

MOPIC/ALAMY STOCK PHOTO

AGB stars have long lives of around a few to 10 billion years before they grow into giant stars and throw off a shell of gas as a planetary nebula. The chance that there would have been such a star in the neighbourhood is pretty small.

Wolf-Rayet stars, on the other hand, don't last long. It is sometimes said that massive stars are like rock stars: they live fast and die young. Stellar evolution models reveal that they shed vast amounts of many different elements in their later lives. More importantly, Wolf-Rayet stars release a lot of aluminium-26, but no iron-60.

These stars also have dense, supersonic winds that sweep up material around them to form a thin, dense shell. These bubbles then continue to expand until they reach pressure equilibrium. We calculated that the amount of aluminium-26 coming from the star, combined with material in the dense shell around it, could be enough to form the Solar System.

One puzzle was how the material gets injected into the shell. If you have a fan blowing in your room, air will hit a wall but not necessarily inject stuff into it. The winds from Wolf-Rayet stars contain dust – we can see it as infrared emission from mostly carbon grains around one micron in size. Because the winds are hot, we hypothesise that the aluminium-26 condenses onto the dust. The dust can be carried out with the wind, reaches the dense shell and penetrates it.

And since there is observational evidence which suggests that stars do form in the dense shells of these bubbles – why not our star?

Next we plan to refine our modelling by checking other isotopes which existed in the early Solar System, and whose abundances we can measure in meteorites. We will see whether a Wolf-Rayet star can provide them in the right quantities.

ABOUT VIKRAM DWARKADAS
Professor Dwarkadas is a Research Associate Professor in the Department of Astronomy and Astrophysics at the University of Chicago


Telescope House
Telescope Specialists Since 1785
Web: www.telescopehouse.com
Email: sales@telescopehouse.com
Tel: 01342 837098
Sign Up
To Our Mailing List
TeleVue
TELEVUE: THE WORLD'S GREATEST EYEPIECES AND ACCESSORIES. AVAILABLE ONLINE AND IN-STORE AT TELESCOPE HOUSE.
NEW DOBS!
6-inch - £267
5-inch £178
Introducing the new Bresser Messier 5 and 6 inch Dobsonians Both come with two eyepieces, fully de-mounteable tubes with mounting rings, are prime focus astrophotography capable
EXPLORE SCIENTIFIC
Explore Scientifc 127mm FCD100 Carbon Fibre Apo £2287
G11 £3563
Telescope House bring you two revolutionary mounts: the observatory class Explore Scientific Losmandy G11 & the ultraportable Exos 2 PMC8 wireless German Equatorial systems
Open GOTO
ExploreStars
PMC EIGHT
PRECISION MOTION CONTROLLER
Exos 2 £892
Explore Scientifc Losmandy G11 PMC8 Wireless EQ Mount
Both feature class-leading drive systems, the brand new Open Goto wireless control and autoguiding
Explore Scientifc Exos 2 PMC8 Wireless EQ Mount
Explore Scientifc Maksutov Newtonian - £892
Bresser Astrophoto Tracking Mount From £265
NEW!
The Bresser Astrophoto Tracking Mount is designed to be used with DSLRs and small telescopes for long duration astrophotography, providing a tracking platform to counteract the Earth's rotation and create wonderful wide field shots of the skies above us.
Available in head only and wedge tripod configurations
Explore Scientific Sun Catcher Solar Filters From £18
HOT PRODUCT 2015 SKY
Lunt LS50 - From £1183
Excellent pressure-tuned portable Solar Scope
Explore Scientific Solarix Solar Film Filter £18
Lunt LS60 - From £1880
Excellent Value 100% Safe Solar Film. Ideal for DIY!
Lunt LS80/B1800 - £5214
Lunt LS100/ B1200 - £6478
Find the full range of ZWO Cameras at Telescope House
Altair USB3.0 Hypercams Deepsky & Planetary Imaging from £349
Bresser Full HD USB Camera/ Eyepiece £50
NEW! ZWO ASI1600 Pro Sensor Cameras See site for offers!
Bresser Saturn 20x60mm Binocular + Tripod Megadeal - £99
Website: www.telescopehouse.com | Email: sales@telescopehouse.com | Tel: 01342 837098
Telescope House, Unit 22 Warsop Trading Estate, Hever Road, Edenbridge, Kent TN8 5LD
All prices correct at time of press. Subject to change. Errors and omissions excepted.

THE SOUTHERN HEMISPHERE IN MAY

With Glenn Dawes

WHEN TO USE THIS CHART

1 MAY AT 00:00 UT
15 MAY AT 23:00 UT
31 MAY AT 22:00 UT

The chart accurately matches the sky on the dates and times shown. The sky is different at other times as stars crossing it set four minutes earlier each night. We've drawn the chart for latitude –35° south.

MAY HIGHLIGHTS

Jupiter is at opposition on the 9th and is at its brightest (mag. –2.5) and largest (44.8 arcseconds) for the year. Being up for the whole night leaves plenty of time to enjoy its cloud banding, the Great Red Spot and the dance of its Galilean satellites as they transit the planet's disc and pass behind in occultation and eclipse. Occasionally all four moons can gather on the same side of the planet – look out for this happening on the evenings of 17th and 31st or the morning of 26th.

STARS AND CONSTELLATIONS

Orion isn't the only body in the cosmos to be accompanied by two dogs. Low in May's northern evening sky lies the constellation of Boötes, the Herdsman, looking like an inverted kite. Preceding him is Canes Venatici, the Hunting Dogs. Named Clara and Asteron, they're joined to him by a leash. The fourth brightest luminary in the heavens is Boötes's alpha star, Arcturus. The herdsman is pursuing the Greater Bear (Ursa Major), which isn't visible from most of Australia.

THE PLANETS

As Venus prepares to depart, low in the northwest twilight, Jupiter can't be missed rising in the east and remaining visible all night. Following this gas giant is Saturn and then Mars, both visible near the teapot of Sagittarius in the east before midnight. Neptune rises around 01:00 UT mid-month, with Uranus returning from solar conjunction. Mercury concludes its favourable morning return. Dropping towards the Sun, it becomes a dawn-only object by mid-May.

DEEP-SKY OBJECTS

Of all the joys Virgo has to offer, the Sombrero Galaxy is awesome! This spiral galaxy, M104, pictured below, (RA 12h 40.0m, Dec -11° 37') looks just like its images. A dark equatorial lane bisects the galaxy, reducing its southern hemisphere to a subdued band. M104, aka NGC4594, is located 5° north-northeast from naked-eye star, Eta Corvi.

Move 1.1° west-southwest from the Sombrero to find the 'Stargate' asterism. It can best be described as two nested triple stars, with the distinctive outer three members (mag. +9.8, +6.7, +6.6) forming a triangle with sides 5 arcseconds long. The inner triple has two prominent (mag. +7.9, +8.3) stars, separated by 29 arcseconds, with a mag. +11.3 companion that forms a right-angled triangle.

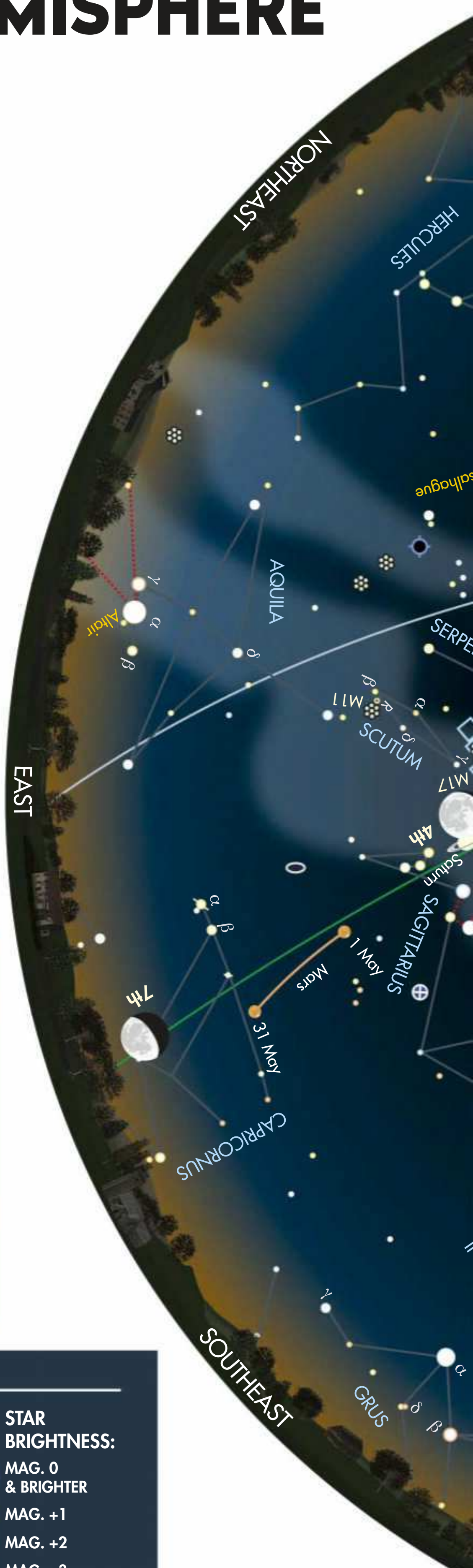
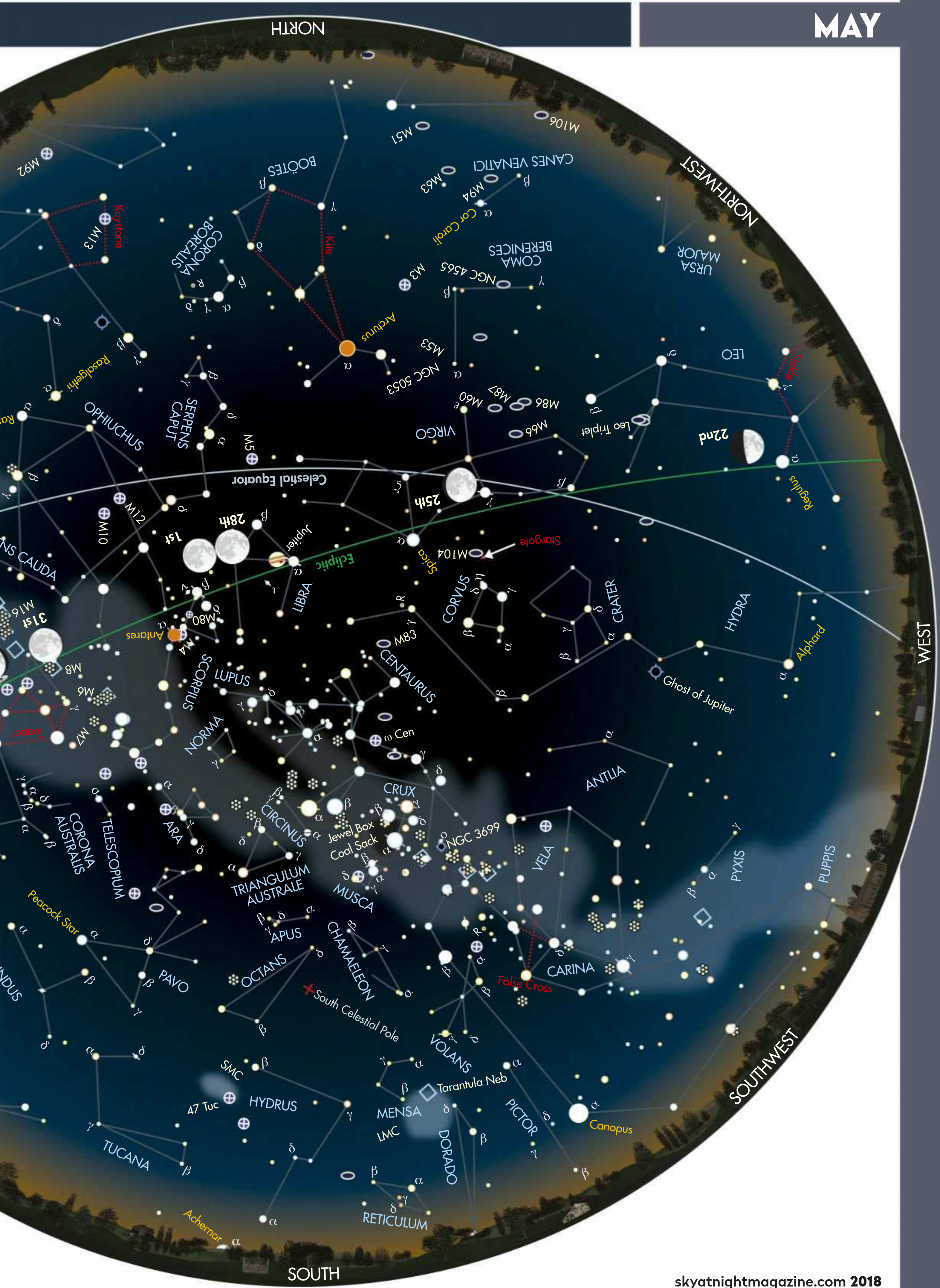


CHART KEY

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET

STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
M106
M51
CANES VENATICI
M63
M94
Cor Caroli
URSA MAJOR
COMA BERENICES
NGC 4565
M3
BOÖTES
Kite
M92
M13
Keystone
CORONA BOREALIS
Arcturus
M53
NGC 5053
LEO
Sickle
Rasalgethi
OPHIUCHUS
SERPENS CAPUT
M5
M60
M87
M86
M66
M65
Leo Triplet
VIRGO
22nd
Regulus
Celestial Equator
25th
M12
M10
28th
1st
Jupiter
Ecliptic
Spica
M104
Stargate
LIBRA
CORVUS
CRATER
HYDRA
SERPENS CAUDA
M16
31st
M80
M4
Antares
M83
CENTAURUS
Alphard
Ghost of Jupiter
M8
M6
M7
Teapot
SCORPIUS
LUPUS
NORMA
ω Cen
ANTLIA
CRUX
CIRCINUS
Jewel Box
Coal Sack
NGC 3699
CORONA AUSTRALIS
TELESCOPIUM
ARA
TRIANGULUM AUSTRALE
MUSCA
VELA
PYXIS
PUPPIS
Peacock Star
APUS
CHAMAELEON
PAVO
OCTANS
South Celestial Pole
CARINA
False Cross
INDUS
VOLANS
SMC
47 Tuc
HYDRUS
Tarantula Neb
MENSA
LMC
DORADO
PICTOR
Canopus
TUCANA
RETICULUM
Achernar

Sky-Watcher®

AZ PRONTO & AZ5 Alt-Azimuth Telescopes

These new lightweight and highly portable grab-and-go telescope ranges combine the thoughtfully designed and well-engineered AZ PRONTO and AZ5 DELUXE Alt-Azimuth mounts with proven high quality Sky-Watcher optics. Each model comes complete with an adjustable aluminium tripod with accessory tray and supplied with two manual flexible slow-motion cables, for easy vertical and horizontal fine motion control. Tracking is smooth and precise via their continuous worm-gear movements. The mount can also be moved around each axis manually, for rapid panning and elevation adjustments. It is often said that the best telescopes are the ones which get used most often - These new ranges are quick to assemble, extremely easy to use and are refreshingly brilliant in their convenient functional simplicity, that will encourage regular use by both beginners and seasoned observers alike!

AZ PRONTO ALT-AZIMUTH RANGE

SRP £219

Prod.Code 10272

EXPLORER-130PS (AZ PRONTO)
130mm (5.1") f/5 PARABOLIC NEWTONIAN REFLECTOR
With an extremely useful 130mm of light gathering aperture and a superb parabolic primary mirror, this is a highly capable all-rounder for the observation of the Moon, bright planets, nebulae, galaxies and star clusters. Supplied with 10mm & 25mm Eyepieces and Red Dot Finder.

SKYMAX-102 (AZ PRONTO)
102mm (4") f/12.7 MAKSUTOV-CASSEGRAIN
The Maksutov's high-resolution multi-coated optical system, excels at medium-to-high powers for the examination of the surface detail of the Moon, planets and also for double-star observations. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.

SRP £299

Prod.Code 10270

SRP £259

Prod.Code 10271

EVOSTAR-90 (AZ PRONTO)
90mm (3.5") f/10 REFRACTOR
A classic two-element, air-spaced, multi-coated achromatic refractor. With its long focal length it is ideal for the detailed high-power study of the Moon & planets. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.

AZ PRONTO MOUNT & TRIPOD
Prod.Code 20317 **SRP £139**

AZ5 DELUXE ALT-AZIMUTH RANGE

STARTRAVEL-102 (AZ5) *Prod.Code 10261*
102mm (4") f/4.9 REFRACTOR
Ideal multi-coated instrument for the widefield observation of deep-sky objects, such as nebulae, star fields, star clusters and galaxies. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.

SRP £379

AZ5 MOUNT & TRIPOD
Prod.Code 20311
SRP £229

AZ5 MOUNT HEAD ONLY
Prod.Code 20312
SRP £159

SRP £299

Prod.Code 10260

EXPLORER-130PS (AZ5)
130mm (5.1") f/5 PARABOLIC NEWTONIAN REFLECTOR
With an extremely useful 130mm of light gathering aperture and a superb parabolic primary mirror, this is a highly capable all-rounder for the observation of the Moon, bright planets, nebulae, galaxies and star clusters. Supplied with 10mm & 25mm Eyepieces and Red Dot Finder.

SRP £499

Prod.Code 10262

SKYMAX-127 (AZ5)
127mm (5") f/11.8 MAKSUTOV-CASSEGRAIN
The Maksutov's high-resolution multi-coated optical system, excels at medium-to-high powers for the examination of the surface detail of the Moon, planets and also for double-star observations. Can also be used for daytime terrestrial observing. Supplied with 10mm & 25mm Eyepieces, 90° Erect Image Diagonal and 6x30 Finderscope.

76 Page Colour Catalogue | **Order Your FREE Copy Today** | **EMAIL: info@opticalvision.co.uk**

Our Products are Available from Dealers throughout the UK OVL **Please contact us, or Check our Website for your Nearest Stockist**

OPTICAL VISION LTD
UNIT 3, WOOLPIT BUSINESS PARK
WOOLPIT, BURY ST. EDMUNDS
SUFFOLK IP30 9UP

OPTICAL VISION LIMITED
www.opticalvision.co.uk

Importers and Distributors of Sky-Watcher Astronomical Telescopes, Helios, Acuter, Barr and Stroud Binoculars & Spotting Scopes and Zenith Microscopes.